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MOISTURE PROBLEMS IN BUILDINGS

Phase 1 Final Report

For

Southern Division  
Naval Facilities Engineering Command  
P. O. Box 10068  
Charleston, South Carolina 29411

December 1978

Contract Number N62467-76-C-0696

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## EXECUTIVE SUMMARY

The purpose of this study was to investigate moisture problems in air conditioned buildings in humid climates and to make recommendations in order to avoid these problems in new construction and to correct these problems in existing buildings.

The moisture problems include the growth of mold and mildew on and in buildings, uncomfortably high humidity conditions within the buildings, condensation, drips and leaks within the buildings and the odor, discomfort and damage to property associated with these moisture problems.

Field investigations were undertaken at various locations in the Pacific and in the Southeastern United States in order to observe the problems under a wide variety of conditions.

Hourly weather data for a one year period was obtained for some of the locations with the most severe problems and analyzed to determine the extent and significance of weather on the moisture problems.

A review was made of the design criteria utilized in the design of these buildings and an analysis was made to determine the influence that the criteria had on the existence of moisture problems. The fundamental and applied principles of building design, thermal and moisture performance of building materials and performance of air conditioning systems were analyzed to determine those criteria which influenced the moisture problems, and to develop design guidance.

A detailed computer analysis was performed on a portion of one bachelor enlisted quarters in one of the more severe locations in order to evaluate the operating and comfort conditions associated with various types of air conditioning systems and the influence that moisture vapor flow had on air conditioning energy requirements and comfort.

Recommendations are made for changes in design criteria in new building construction to eliminate moisture problems. Recommendations are also made for corrective action in existing buildings.

In order to preclude moisture problems in air conditioned buildings in humid climates it is necessary to insure that the building structure is capable of minimizing heat and moisture flow as well as surface condensation, and that the air conditioning system employed is capable of maintaining comfort conditions with humidity control under all conditions experienced by the building throughout the year. Primarily this involves the selection of an air conditioning system that is capable of controlling humidity continuously.

Since virtually all of the existing buildings that experience moisture problems utilize fan coil type air conditioning systems which are not capable of controlling humidity, the corrective action recommended is to replace the complete air conditioning system in conjunction with changes to the building.

## CHAPTER 1

### INTRODUCTION

#### Statement of Problem

The purpose of this study is to investigate moisture problems in buildings and to make recommendations for correction. The background and objective for this project are taken from the Navy description of engineering services:

In the last several years numerous moisture problems have been encountered in Navy buildings. Most of the problems have been in BEQ's and dormitory type structures; however, other building types are also involved, the problems are very complex and solution on a routine basis has not been satisfactory. Examples of problems encountered have been reported by SOUTHNAVFACENGCOM, PACNAVFACENGCOM and LANTANAVFACENGCOM. Lack of technical information and understanding of the phenomena which contribute to this problem must be overcome and adequate design solutions developed to preclude recurrence in future construction.

The objective of this project is to: (a) Identify the major types of building construction and types of environmental conditioning systems which contribute to moisture condensation, humidity, and mildew problems during the cooling season for sub-tropical and tropical environments, (b) Investigate the type of buildings and systems found in (a) and determine the contributing factors and (c) Develop recommended design practices and corrective measures required to preclude moisture condensation, humidity, and mildew problems.

Throughout this report the words mold and mildew are used extensively without any precise definition of what they are. Essentially we are talking about discoloration and growths on the various surfaces of a building. Molds are caused by

fungi, which are microscopic threadlike plants. Their growth depends upon suitable temperatures, dampness and air. The discoloration may occur as specks, spots, streaks, or patches of varying intensity and color. The exact color depends upon the particular organisms. Mold discolorations usually first become noticeable as largely fuzzy or powdery surface growths, with colors ranging from light shades to black. Among the brighter colors, green and yellowish hues are common. The most common colors found in this investigation were black and dark gray.

#### Problem Outline

An outline of the basic problems is shown in Table 1-1. The evidence for each of the major problems is also shown in this Table.

#### Exterior Surface Condensation

Discoloration of the exterior surfaces of buildings in humid climates is among the most significant of the problems investigated. This discoloration is caused by mold and mildew primarily as a result of moisture on the exterior surface of the building.

The problem was most evident on exterior walls in the more humid locations where the walls were poorly insulated. So long as the exterior surface temperature of the wall was

TABLE 1-1

BASIC PROBLEMS

<u>PROBLEMS</u>	<u>EVIDENCE</u>
1. Exterior Surface Condensation	Mold and Mildew
A. Walls	
B. Projections (Floors)	
C. Columns	
D. Interior Corners	
E. Orientation	
F. Air Flow	
G. Clear Sky Radiation	
H. Building Mass	
2. Vapor Flow Into Building	Latent Cooling Load
A. Through Materials	
B. Open Windows and Doors	
C. Exhaust Systems	
D. Ventilation Air	
E. Infiltration	
3. Condensation In Building Materials	Destroys Finishes
4. Inability to Dehumidify	Mold and Mildew
A. Ceiling Tiles	
B. Walls	
C. Closets	
D. Saturated Cooled Air	
E. Chilled Water Temperature	
F. Lower Room Temperatures	
G. Aggravates 1,2,3 & 5	
H. Fan Coil Units	
5. Interior Water	Mold, Mildew, Rusting
A. Wet Coils	
B. Drain Pans	
C. Drain Pan Overflow	
D. Pipe Insulation	
E. Diffusers + Fan Coil Units	
F. Showers	
G. Laundry	
H. Walls, Ceilings and Floors	

below the dew point of the ambient air condensation will occur. With poorly insulated walls in air conditioned buildings this situation will occur with great frequency. The less humid the climate and the better insulated the wall, the smaller the magnitude of this problem.

Discoloration occurs on the projections from buildings. Since many buildings in tropical humid climates have horizontal exterior shading devices to minimize solar heat gain, these horizontal projections become cooled below the ambient air dew point temperature when the interior of the building is air conditioned and when the flow of heat is not interrupted. This can be called a cold radiator effect.

Discoloration also occurs on columns and foundations of buildings in humid climates when the buildings are air conditioned. ~~Common construction practice in warm climates does not call~~ for these building elements to be insulated.

The most predominant discoloration occurs on interior corners of buildings between walls and horizontal and vertical projections. It is at these areas where it is most difficult to properly insulate an air conditioned building so that these interior corners tend to be at a lower surface temperature than the surrounding expanses of material.

Discoloration occurs more frequently on northern facades of buildings than on any other facade. Since surface condensation will occur on the coldest surfaces, and since the north

facing surface gets the least sun, it generally has a tendency to be the first one to exhibit discoloration. Fixed shading devices, such as overhangs, can also contribute to this problem in any orientation. Discoloration is more prevalent in the shaded areas of walls than in the unshaded areas due to the ability of the sun to warm up the exterior surface of the wall and raise the temperature at which condensation will occur.

Since it is necessary to have moisture present for mold growth, air flow or lack of it can contribute to the presence of mold. This becomes most noticeable on interior corners and on various projections from a building, such as exterior stairwells. Any projection or corner that inhibits air flow wiping the surface will create a situation in which mold growth can occur. With a surface exposed to air flow the tendency is for any surface moisture to evaporate more quickly than if there were no air motion.

Clear sky radiation at night has been found to depress the surface temperature of building materials to as much as 10 degrees F below the ambient dry bulb temperature. In humid locations the ambient dry bulb temperature and the ambient dew point temperature are very close for the majority of hours in a year. Under these conditions there can be frequent occurrences of surface condensation due to clear sky radiation at night.

The mass of a building can have some influence on the incidence of mold growth. This is most pronounced in poorly insulated

buildings, where the exterior surface of the building can cool off more rapidly during diurnal cycles of temperature. The more massive building construction tends to retain its heat longer and therefore stay warmer at night.

#### Vapor Flow Into Building

Moisture vapor flowing into buildings not only creates additional latent cooling loads, but when it exists in sufficient quantities can also condense on the relatively colder interior surfaces of the building.

Moisture vapor flows through all types of building materials and vapor barriers to varying degrees. In climates with high ambient dew point temperatures, there is a dramatic difference in vapor pressure between the ambient air and air conditioned spaces. While the basic principles of vapor flow through building materials are well known, the accuracy with which they can be calculated and/or predicted are questionable.

Vapor flows into buildings through open windows and doors. Windows are usually under the control of the occupants of the building and when the air conditioning system does not perform to their satisfaction, they will open windows in an attempt to obtain some relief. Doors to the exterior are found to be open either as a matter of convenience in high traffic buildings or due to a lack of maintenance. Door closers have not been repaired and occasionally doors do not fit well and/or do not close tightly.

Exhaust systems which remove more air than is being supplied

to a building will cause infiltration of ambient air.

Ventilation system which brings in outside air without continuously dehumidifying it will add substantial quantities of vapor to the spaces in a building.

Infiltration of ambient air will bring vapor into the spaces in a building under conditions of high ambient dew point. Recent studies have shown that infiltration through other than windows and doors can account for a substantial proportion of the total infiltration air. These areas include vents, louvers, stacks, flues, electrical wiring, plumbing, construction joints, etc. Details of construction regarding the air tightness of these things are not usually considered in any great depth in the design of air conditioned buildings in humid climates.

#### Condensation In Building Materials

So long as moisture is flowing through an element of a building, that moisture will condense if it reaches a material at its dew point temperature. This problem becomes aggravated when the moisture flow is continuous during all months of the year. In climates that have dry seasons or heating seasons, any entrapped moisture in the construction usually has a chance to escape by virtue of the reversal of the vapor pressure differences. Where condensation occurs in building materials it can have varying effects. In insulation, condensed moisture will reduce the thermal resistance of the insulation thereby causing more heat flow through the building element and frequently aggravating the moisture condensation.

When condensation occurs at the interface between a building material and a finish, that finish can flake or spall. When condensation occurs in materials such as gypsum wallboard it not only will weaken the material but it will also increase its weight substantially. When the wallboard is used on a ceiling, the increase in weight can be sufficient to cause the ceiling to fall. Moisture condensation can also cause staining of finished surfaces and loosening of wall and ceiling coverings.

#### Inability To Dehumidify

The inability of an air conditioning system to adequately and continuously dehumidify the space can cause a number of problems. The growth of mold is significantly enhanced in humid atmospheres. Building materials may become wet. The occupants may attempt to take actions such as lowering the temperature in an effort to achieve comfort.

Most types of materials used in suspended acoustical ceilings do not function properly in humid atmospheres. The moisture causes them to swell and sag, frequently falling out of the suspension system.

The inability to dehumidify can cause surface condensation on walls when humid air enters the space and the walls are at a temperature lower than the dew point. Higher levels of activity that generate moisture, especially showering, may take hours to dissipate when the ability of the air in the room to absorb moisture is limited. Thus, the dew point temperature of the air in the room can be above the surface temperature

of the interior surfaces, causing condensation.

With high levels of humidity, moisture can accumulate in closets due to damp materials being stored and the relative lack of air motion which would permit the moisture to be dissipated. The lower the moisture content of the conditioned space, the less likely this problem will be.

Moisture can condense on interior surfaces when cold saturated air is discharged directly on to those surfaces. When cold discharge air from an air conditioning system impinges on a surface, that surface will tend to approach the temperature of the air. When the air conditioning unit cuts back in capacity and undehumidified air strikes that cold surface, condensation will occur.

In order for any air conditioning system to adequately dehumidify it is necessary that the cooling medium be maintained at a sufficiently low temperature. In humid climates this temperature should be no higher than about 42 or 43F and continuously maintained at that temperature. Problems with the operation and maintenance of air conditioning systems cause these temperatures not to be achieved, either occasionally or continuously. When this happens for periods of longer than a few days, the propensity to develop mold growth is significantly enhanced.

When dehumidification is not achieved, the occupants will sometimes attempt to obtain comfort by operating the air

conditioning system at a lower room temperature. Even when the control system will not ordinarily permit lower temperatures to be achieved, the occupants can be exceptionally creative in discovering means for doing this.

The inability to dehumidify can frequently aggravate the many other problems associated with moisture in air conditioned buildings in humid climates.

Almost every building that we investigated that had moisture problems utilized some type of fan coil air conditioning system. There are numerous problems associated with the use of fan coil units for air conditioning in humid climates. With the relatively low capacities required for sensible cooling, most fan coil units are only provided with one or two row coils, thus limiting their dehumidification capability from the beginning. The chilled water distribution network to serve fan coil units is necessarily complex and the pipe sizes are typically small due to the low cooling loads for the units themselves. This makes the balancing of chilled water flow a difficult and demanding task, which frequently needs to be accomplished on a periodic basis due to various and sundry reasons. Also, since much of the piping is small and since the balancing valves must frequently be almost fully closed, there is a tendency for any impurities in the chilled water system to become lodged at the balancing valves or in the small piping, thus rendering some fan coil units unable to cool and/or dehumidify. Almost all

of the fan coil unit systems observed utilized openings in the wall for the purpose of bringing in ventilation air. Beside the difficulty in controlling the quantity of outside air introduced, there are problems associated with dehumidifying this outside air when the fan coil unit is operating at less than its full rated load. This problem becomes even more aggravated when the fan coil units are oversized or when there are a few days that require a larger fan coil unit. Under these conditions the fan coil unit operates at an even lower average load condition, thus providing even less dehumidification, if any.

The methods of temperature control for fan coil units vary with the designer and are subject to maintenance problems, which are further aggravated by the inability to achieve comfort, since the occupants will attempt to operate (or destroy) the controls in an effort to achieve comfort. When fan coil units are used, either with or without outside air being brought in through the unit, some type of cyclic control is necessary either on the fan, or on the chilled water, or both. Cyclic control will not permit continuous controlled dehumidification to occur. Also, when exhaust systems remove much more air than is brought in through the fan coil unit, the proportion of outside air relative to room air increases, and the location of the sensing bulb for the thermostat (which most often is in the return air stream) will sense a greater influence from the ambient temperature and can cause loss of control and overcooling.

### Interior Water

Many of the moisture problems are associated with interior water of one form or another causing mold, mildew, rusting, destruction of finishes and condensation.

When air conditioning systems must run almost continuously, the cooling coil will remain wet almost continuously in a humid climate. This creates a condition which is conducive to rusting and the build up of various types of deposits and growths. It is not known whether there is any health problem associated with these buildups, since we are not aware of any studies that have been done on this subject.

With long hours of operation cooling coil drain pans are filled with water to the overflow almost continuously. This provides the opportunity for the buildup of deposits and the growth of mold and mildew. These drain pans also are collectors of various and sundry rubbish, lint, etc., which can clog the drain pan outlet and cause it to overflow. Since most of the air conditioning units are located in the occupied space, either on a wall or in a ceiling soffit, any overflow will usually cause water damage to the building.

In fan coil units there is a supplementary drain pan underneath the piping connections, control valve and the end of the cooling coil in order to collect any condensation from these parts. The problems with these drain pans are similar to those of the main drains underneath the cooling coil.

Since the drain lines running away from the fan coil units are small, they too can become clogged and cause condensate to back up and flow into the occupied space or into other portions of the building.

Moisture problems exist with pipe insulation. There are various reasons including improper sealing of the vapor barrier and the ends and special fittings in the piping system, condensation on the surface of the insulation due to high ambient dew points, and the saturation of the insulation due to the constant vapor pressure differential throughout the year and the inability of the insulation to "dry out" during a heating season or shut down hours of the chilled water system. As the insulation becomes more saturated due to the vapor pressure differential, the thermal resistance drops so that the surface temperature of the insulation drops below the dew point of the room faster.

Condensation occurs on diffusers, registers and fan coil units with the cold supply air blowing on them in conjunction with space conditions at high dew point temperatures. Beside rusting ferrous materials, this surface condensation is frequently of sufficient quantity to drip and run into the occupied space and destroy or damage property.

Beside the high concentration of water vapor in the shower room itself, moisture vapor diffuses throughout the entire enclosed space so that when the surface temperatures are below the dew point, condensation will occur.

In many air conditioned buildings in humid climates there are some rooms that contain high heat and/or moisture producing processes. Even though those rooms may not be air conditioned and even though they may be "closed off" by means of a door from the rest of the building, any moisture generated in those rooms can diffuse throughout the building and frequently the occupants will open the doors to conditioned areas to attempt to achieve greater comfort. One such example would be a laundry room.

The various sources of interior water along with vapor flow into a building and high humidity conditions in an air conditioned building will cause the growth of mold and mildew wherever that water has an opportunity to exist for any length of time.

#### Method of Approach

Field investigations were made in various Naval installations in the Pacific and in the Southern United States where humid climates prevailed. The conditions observed were documented and measured where possible.

Hour by Hour weather data for a one year period was obtained for several of the more humid locations and analyzed to evaluate the frequency and significance of the ambient humidity conditions.

The pertinent Department of Defense and U.S. Navy design criteria, design documents and reports were reviewed in light of the problems with moisture in buildings. An analysis

was made of the problems in order to develop recommendations. Recommendations were made for changes in design criteria and for general guidance in new construction as well as for corrections to the problems in existing buildings.

CHAPTER 2  
FIELD INVESTIGATION  
PACIFIC

Purpose

There were several purposes for this field investigation:

1. To make an initial observation of the moisture problems in Enlisted and Officer Quarters in Hawaii, Guam and the Philippines.
2. To see if the modifications made to date have performed adequately.
3. To see if other possible solutions come to light as a result of seeing the buildings and modifications thereto.
4. To comment on the proposed modifications to improve conditions at the buildings at Cubi Point which were prepared by the ROICC in Manila.
5. To see if improvements can be made and implemented prior to the next rainy season.
6. To receive a briefing from Pacific Division and debrief them on our return.

We also briefed Captain Weis, the ROICC in Manila prior to our departure. The results of our trip can best be summarized by the following edited version of our presentation to Captain Weis.

Presentation To Captain Weis  
Manila - November 3, 1976 (Edited)

Introduction

I don't think I have to start off with a description of the

problem. I think you are all well aware of all of its ramifications. What I would like to emphasize is that it is not a single problem. It is a complex problem. There are many contributing factors and I don't care which building you are looking at or which part of the problem you are looking at, there are no single simple solutions. If that were the case, I'm sure you would have accomplished it a long time ago.

Most of the attempts that have been made and are contemplated have been with the existing air conditioning concept. Most of these attempts will improve the condition but won't totally fix it.

### Solutions

I am going to attempt to answer five questions. First, what is a satisfactory solution? Second, will the proposed project provide that solution? Third, if the proposed project is accomplished would any of the work be in vain compared with the long range satisfactory solution? Fourth, were the criteria for a satisfactory solution reduced, will the proposed project be acceptable? Fifth, if reduced criteria are acceptable what can be done to improve the proposed project?

So I would like to start with a description of what is a satisfactory solution. The items that I am going to mention are in no special order, but obviously number one on the list is comfort. Comfort with regard to temperature, humidity and noise. Second, and a minor consideration is health. The health of the occupant with regard to mold growth, algae and bacteria in the rooms on the fan coil units. Third is maintenance, maintenance of the various systems particularly taking into account local conditions and capabilities, and tolerance to variations, tolerance to things like power failures, equipment failures, loss of performance, chilled water temperatures, overflows of drains and the like. Fourth, operating cost and that is primarily energy cost, but also life cycle cost. Fifth, appearance, appearance of the building from the standpoint of mold and mildew, of paint and the general appearance of the building and equipment that the occupant sees. Next, keep complaints at a reasonable minimum. And I don't care too much whether these complaints are too hot or too cold or too noisy, but the documentation that we saw indicates just in one BOQ there is page after page after page of occupant complaints of one sort or another about the air conditioning. Whether these complaints are valid or not, whether they're reasonable or not, is a totally different story; it's the fact that they are complaints. Finally, a satisfactory solution provides an air conditioning system and a building that are reasonably "occupant proof", or in Admiral Fisher's words "sailor proof".

With that in mind will the proposed project provide a satisfactory solution? No. Why not? The major fault is in the selection of the original air conditioning concept and in my

opinion nothing can be done to that basic concept, short of total replacement, that will provide a satisfactory solution.

The major reason is that with the fan coil system concept you can reasonably only control temperature or humidity, not both.

Next, the required maintenance will be increased. One of the problems that we found was that even though there was some maintenance being done, it was not at a sufficient level to maintain the equipment as it was originally designed, or to meet its original design criteria. And if there was ever an area where the need for maintenance was emphasized by virtue of the problem, this is it. Yet in only two out of the approximately 8 or 10 chilled water plants that we visited was the temperature of the chilled water below 50F; 80% of them roughly were well into the 50's which is (a) totally inadequate to do the job and (b) is not nearly what it was designed for. There also appears to be a dilemma in maintenance responsibility, because apparently day to day maintenance responsibility at least at Cubi Point was the responsibility of the Cubi Point housing people rather than the Public Works people.

These are the realistic conditions that these systems are operating under. Therefore the maintenance of the existing equipment at existing levels will still be a problem with regard to things like chilled water temperatures and with regard to overflows of the drains and flooding of the rooms. Admittedly, the problem is not nearly as great with flooding of drains here at Cubi Point as it is in Guam because of the location of the fan coil units. We walked into one room rather arbitrarily in Guam, lifted out a ceiling tile and dumped at least 10 gallons of water. Fortunately the room was unoccupied and didn't destroy much property, except Government property.

The next reason is operating cost. With the proposed fix you are going to approximately double your operating cost. That's an order of magnitude. There are no calculations to back it up, but there will be substantial increases both in cooling energy required and in heating energy required, and that's an expensive proposition. We didn't get any indication as to what it costs to generate electricity. I assume it's not cheap. Well, we assumed on the order of 10¢ per kilowatt hour. In kicking numbers around we talked about an order of magnitude of existing energy costs of about \$100 per room per year. When one considers life cycle cost an increase on the order of \$100 per room per year will pay for a lot of modifications. Other air conditioning concepts probably would have lower life cycle costs but higher initial costs now. Those other concepts, in other words a replacement of the fan coil concept, can provide both satisfaction and possibly provide a lower life cycle cost.

Next, the fan coil system can barely maintain acceptable temperature and humidity conditions during the dry season right now. I have serious doubts that barely acceptable conditions can be maintained even with the fix during the rainy season, due not so much to the basic system itself but due to the nature of the use of the building. Things like windows that don't seal tightly, doors that are left open, occupants coming in and out, wet clothes laying around, etc.

Next, the nature of complaints with the fan coil system deals primarily with those things which will not be changed by the proposed project. That is too cold, overflows of drains and the units not working, in terms of fans not operating or the controls not working.

The next question is if the proposed project is accomplished will any of the work be in vain when compared with a satisfactory solution? The answer to that question is half and half. Essentially the architectural treatment of the buildings themselves such as in closing off corridors, insulating walls and fixing of exhaust systems will not be in vain. In my opinion, any money spent on the fan coil unit system itself to try to improve it will be money wasted when it comes to a proper long range fix.

Now maybe I have been a little too severe in some people's opinion with regard to what constitutes a satisfactory solution. If the criteria for a satisfactory solution are reduced, will the proposed project be acceptable? Here I think it is only fair to say that the improvement to be expected from the proposed project is significant. There's no question about that. The real question is will it go all the way. I don't think so, but it will be a significant improvement.

Indeed, if the system as it exists now were operated as it was originally intended with first class maintenance and continued care and attention, then you would also have a significant improvement in conditions. Those buildings that we visited that were well maintained where chilled water temperatures were in the 40's were significantly better in comfort and mold growth than many of the other buildings where these things have been let go or disregarded or not cared about.

I do not have in mind a specific solution, because you have different conditions in each building such as headrooms, but generally speaking the more satisfactory solutions include a ducted system of one type or another, in which you are first able to control the dehumidification, in which you are able to centralize the removal of moisture and therefore preclude having water in any of the rooms to start with. With the fan coil system you are still going to have drain pans, you are still going to have overflowing. Where is the water going to come from? It's going to come from the moisture that is generated in the room and that leaks into the room,

that all fan coil units are going to have to remove. How are we ever going to do away with that? By not having cooling apparatus in the room, just cold air. The other thing is that centralized air systems are a lot more tolerant to poor maintenance and to equipment failures. Right now if you maintain 55 degree chilled water in lieu of 45 degree chilled water, the humidity goes to hell very quickly whereas with an air handling type centralized system, and when I say centralized system I don't mean per building, I mean per wing or per floor, the inherent capability of the system still permits you to do dehumidification and provide more comfortable conditions.

Another consideration is that in some of the buildings, especially the fiscal year 72 Quarters, the headroom is such so as to make consideration of a ducted system extremely difficult. At this point I wouldn't say impossible, but it certainly appears to be extremely difficult. There a consideration might be a DOD enigma, which is the through the wall air conditioner or window air conditioner.

Now, we also kicked around, and there's no hard backup for this, an order of magnitude of dollars that are involved, construction cost dollars. I have not looked at the existing project to verify or deny the proposed budget which I understand is something around \$600,000. Just in general discussions, in order to do a proper fix and provide a satisfactory solution, we are probably talking about an order of magnitude of an additional million dollars for the buildings that this project covers. Now it could be a half a million and it could be a million two, but it is on that order of magnitude of money. And I think that's that basic command decision, do you want to gamble with what you have for a half a million, or do it right for a million and a half.

The other consideration is schedule and there is obviously a lot of pressure to do a fix before the next rainy season. With the proposed project it appears that you can accomplish that. Unfortunately, with any other solution it's about totally out of the question before the next rainy season.

There is an interesting parallel in DOD, back in the 1950's the Air Force installed about 20,000 heat pumps in family quarters and had failure rates that were astronomical. The result was a DOD ban on heat pumps that lasted from circa 1960 until about a year or two ago.

The only other consideration that I have is in going through the plans that you do have, there are a number of questions and comments that I will have if you intend to proceed with that project. There are a number of things that could be done that would improve that project.

The good things are that the treatment that you propose for the insulation of the buildings, for the changes to the

exhaust systems, and for the enclosing of the corridors are proper and correct viable solutions regardless of which fix you choose.

Let me also be very clear here that we are talking about quarters only. We are not talking about any other type buildings and we are also only talking about tropical locations. The Southern Division has more of these things than you do, but I am not sure that the nature of their problems is quite the same because the nature of their climate is different.

Apparently, in the fixes that have been done both here and in Guam, a substantial proportion of the money has gone for painting. We have found a number of rather serious deficiencies in the painting concepts that are used and in materials that were used. We're taking samples back to analyze them.

Out of professional curiosity we stayed at the Holiday Inn in Manila which has a fan coil system. The building is 3 months old, and there is mold and mildew already. We did the same test at the Holiday Inn on the 16th Floor, and their humidity was about 70%. They may scrub that mold off the walls daily, and they will live with it, and if they get a leak or a drain pan overflow in the room they just won't rent the room.

#### Conclusion

I think the basic decision as to what type of an air system to go to is primarily a life cycle cost decision. My initial guess would be that you could probably justify a variable volume system pretty quickly from an operating cost standpoint. (End of Presentation)

#### Conditions Found

Table 2-1 indicates the more significant items noted during the course of the field investigation on a building by building basis. Mold and mildew was observed to varying degrees in virtually all buildings. In addition to the buildings noted in Table 2-1 we also made brief observations of numerous other buildings. Of the several dozen buildings toured, the only one that exhibited

satisfactory conditions was a BEQ in Guam that utilized a variable air volume system. All of the other buildings that we observed utilized fan coil systems and every single one of those buildings had some type of problem.

Figures 2-1 to 2-5 show psychrometric plots of the conditions found at the various locations. The measured conditions shown were taken at random in various rooms in the buildings, while the ambient conditions were measured in the vicinity of those buildings. Also shown is the ASHRAE comfort envelope and the 1%, 2½%, and 5% design conditions utilized by the Navy.

These conditions were all measured during the dry season so that the ambient conditions were not nearly as high as those experienced during the wet season. Even still, of the dozens of rooms measured, only two of them fell within the ASHRAE comfort envelope. Where the chilled water system was functioning properly there was usually very little problem in obtaining the dry bulb temperature desired. But in almost every case the humidity was out of range and therefore much too high to be considered comfortable.

TABLE 2-1  
ITEMS NOTED DURING  
FIELD INVESTIGATION

Problems	NCS		NAS		NAVMAG		NAS Cubi Point		
	Guam 294-296	Guam FY72WB	1300-01	Guam	Guam 859		8254	8138	8314-17
1. Exterior Surface Condensation									
A. Walls	X		X	X	X				
B. Projections (Floors)									
C. Columns									
D. Interior Corners			X						
E. Orientation	X						X		
F. Air Flow			X				X		
G. Clear Sky Radiation									
H. Building Mass									
2. Vapor Flow Into Building									
A. Through Materials				X				X	X
B. Open Windows and Doors	X		X				X		
C. Exhaust Systems									
D. Ventilation Air									
E. Infiltration			X	X					
3. Condensation In Building Materials	X						X		X
4. Inability to Dehumidify									
A. Ceiling Tiles	X		X		X			X	
B. Walls									
C. Closets									
D. Saturated Cooled Air									
E. Chilled Water Temperature	X		X	X			X		X
F. Lower Room Temperatures							X		X
G. Aggravates 1,2,3 & 5									
H. Fan Coil Units	X		X	X	X		X		
5. Interior Water									
A. Wet Coils									
B. Drain Pans			X						
C. Drain Pan Overflow			X						
D. Pipe Insulation	X								
E. Diffusers + Fan Coil Units	X								
F. Showers									
G. Laundry									
H. Walls, Ceilings & Floors				X			X		X

# ASHRAE PSYCHROMETRIC CHART NO. 1



NORMAL TEMPERATURE  
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY  
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**GUAM**

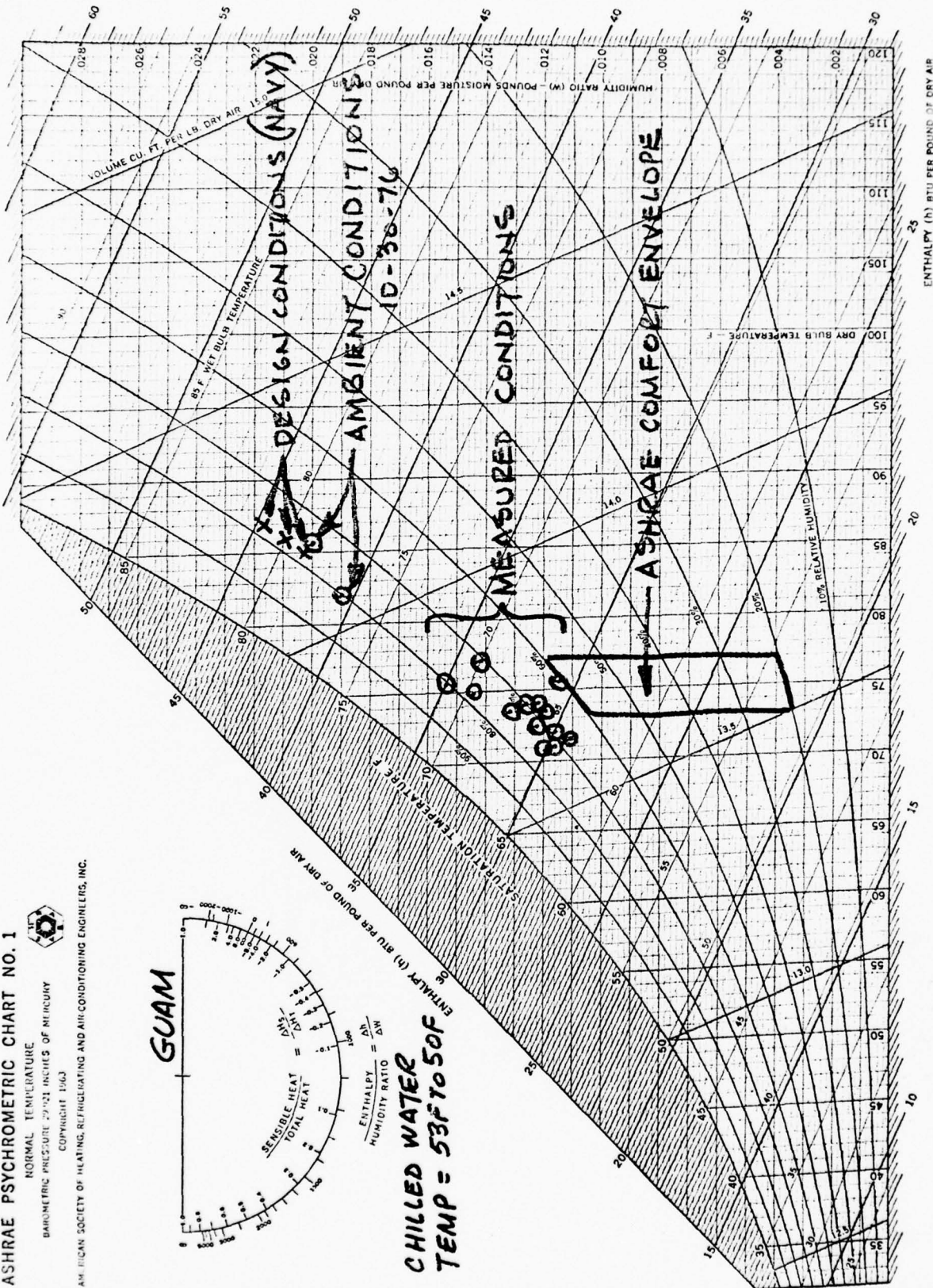
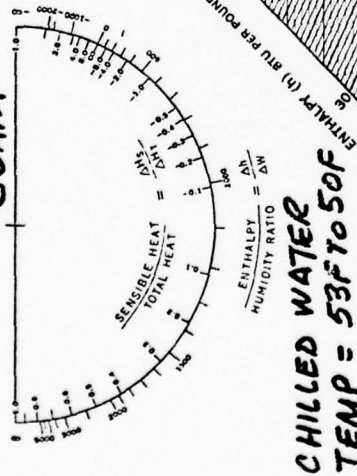


FIGURE 2-1

# ASHRAE PSYCHROMETRIC CHART NO. 1

NORMAL TEMPERATURE  
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY  
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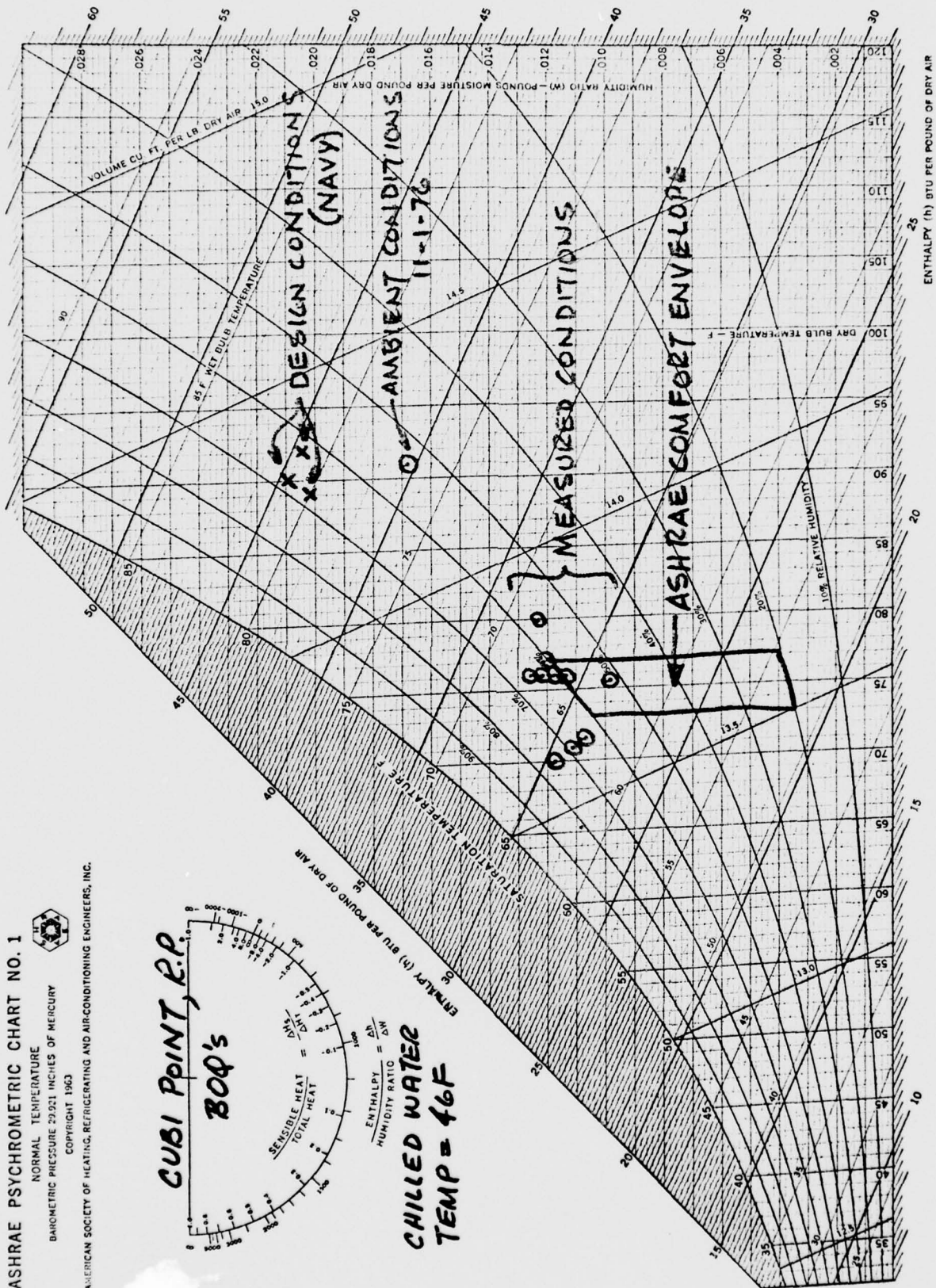
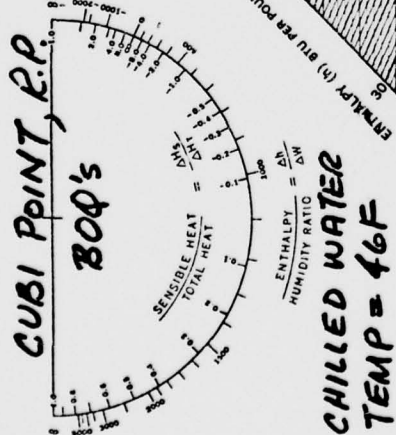


FIGURE 2-2

# ASHRAE PSYCHROMETRIC CHART NO. 1

NORMAL TEMPERATURE  
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY  
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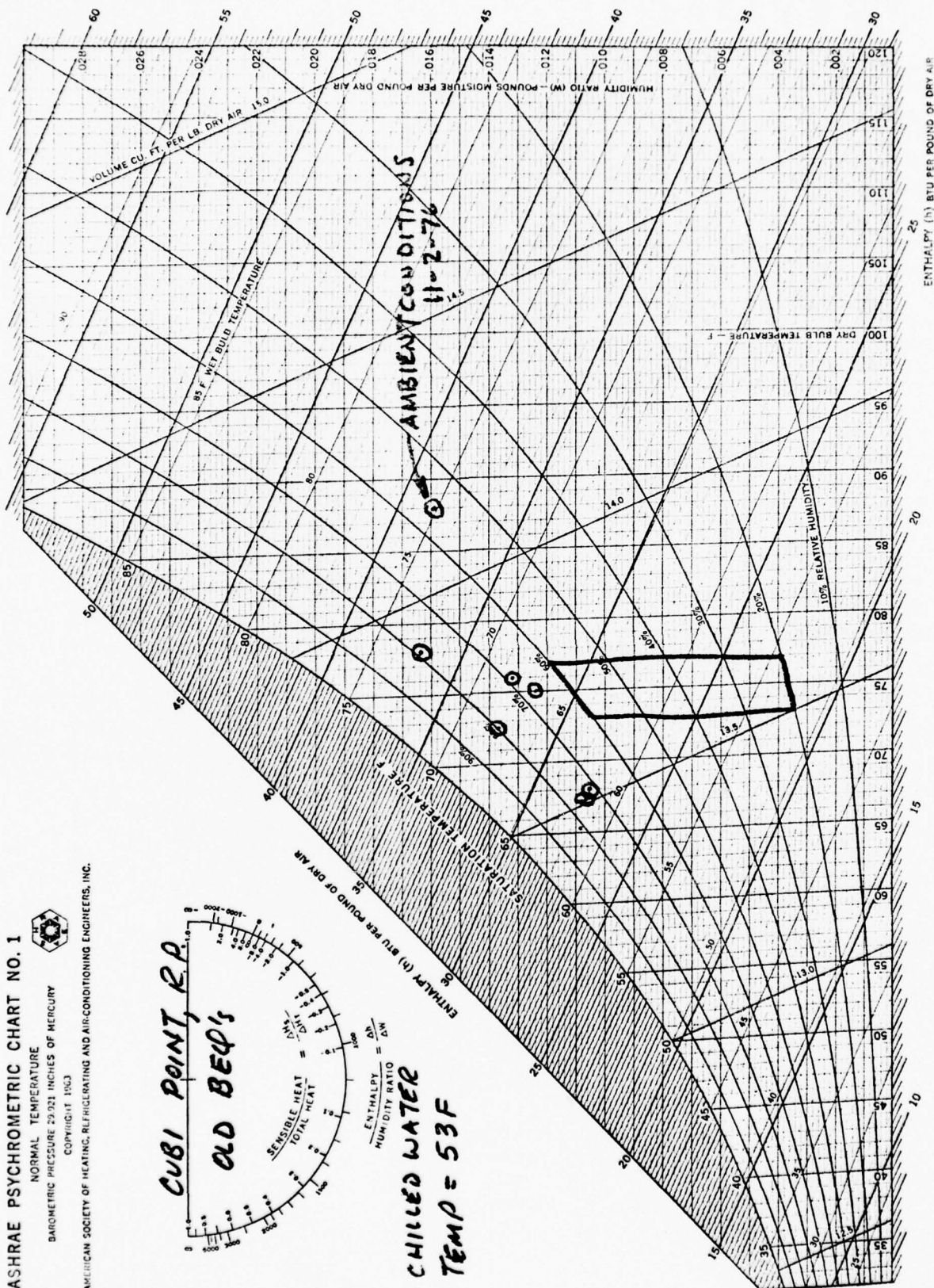
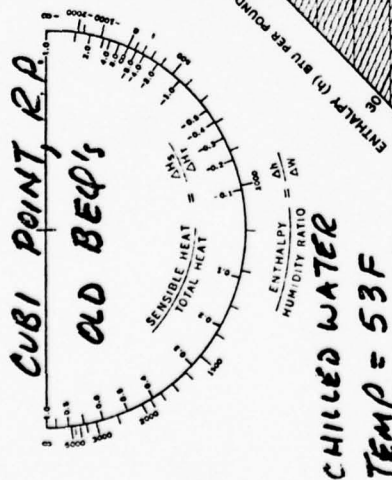


FIGURE 2-3



NORMAL TEMPERATURE

BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY

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CHILLED WATER  
TEMP = 40

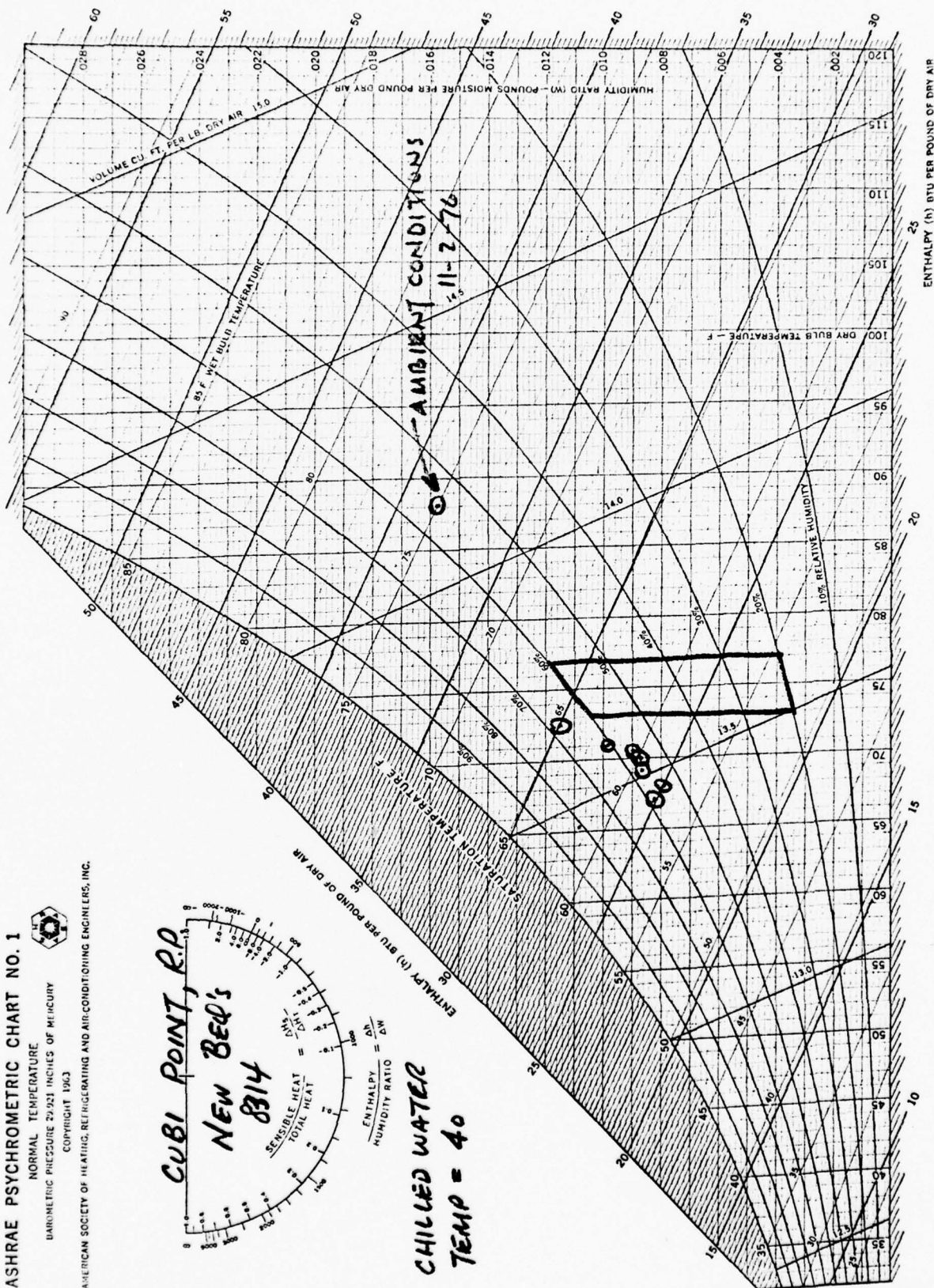


FIGURE 2-4

# ASHRAE PSYCHROMETRIC CHART NO. 1

NORMAL TEMPERATURE  
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY  
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**CHILLED WATER**  
**TEMP = 45F**

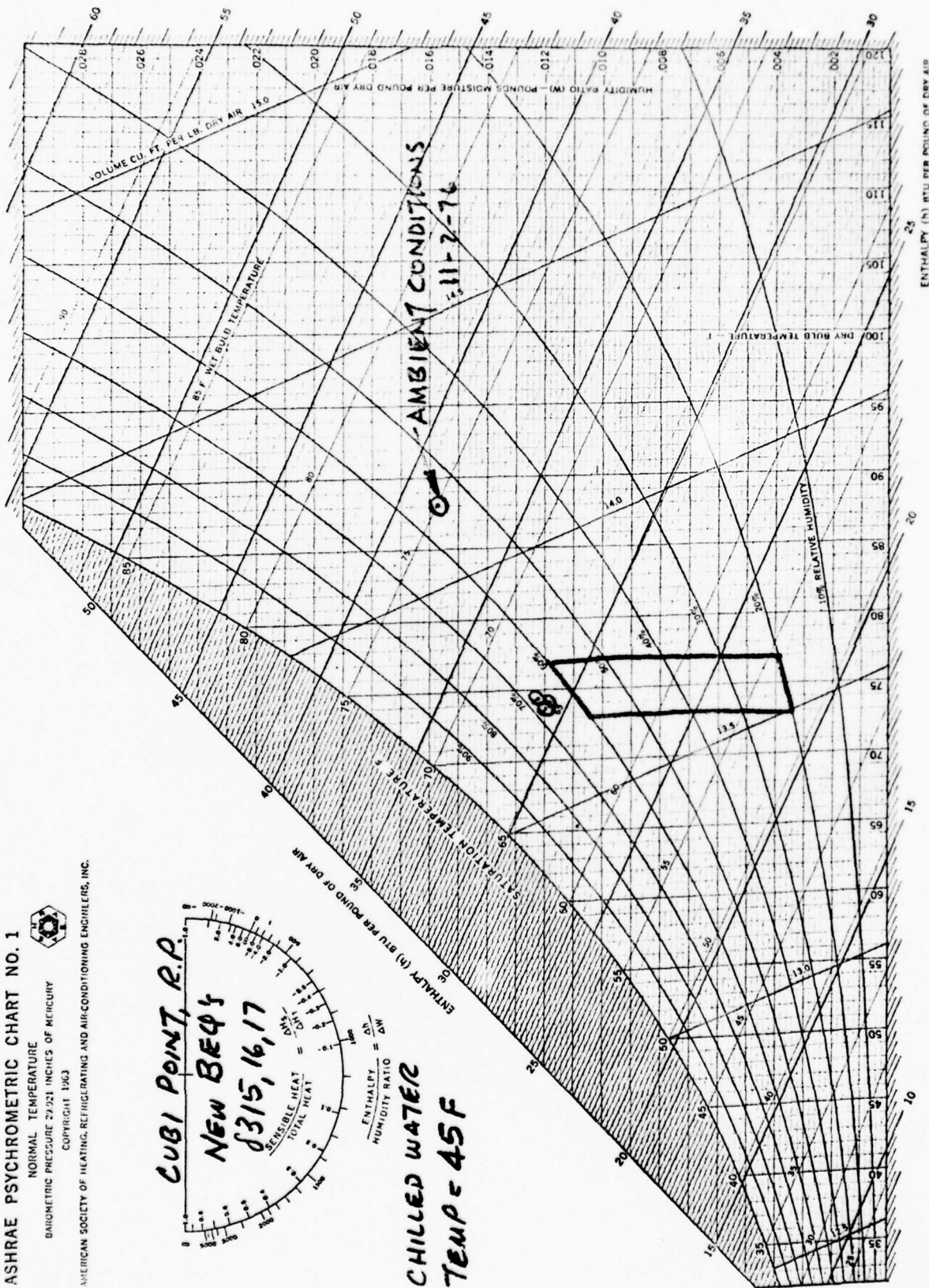


FIGURE 2-5

CHAPTER 3  
FIELD INVESTIGATION

UNITED STATES

Purpose

The purpose of the field investigations in the United States was to determine the problems existing in air conditioned buildings in the more humid climates in the United States. In addition to Bachelor Enlisted Quarters we also investigated a number of other types of buildings including a Commissary, Air Crew Training Buildings and Missile Maintenance Buildings.

We conducted a briefing for personnel of the Atlantic Division and held discussions concerning moisture problems in air conditioned buildings experienced in facilities under their control.

The investigations were conducted in various buildings at the Charleston Naval Hospital, the Pensacola Naval Air Station, Corry Field, the Naval Support Activity in New Orleans and the Naval Air Station in Jacksonville.

Conditions Found

The conditions found during this investigation were very similar to those found in the Pacific, except they were not quite so severe. This is probably due to the fact that the weather in the United States is not quite as severe as it is in the Pacific.

Table 3-1 shows the more significant items that were noted in the various buildings during the course of our investigation. Figures 3-1 to 3-4 show the measured conditions plotted on psychrometric charts. Here again, we found not one single case where the air conditioning system was able to maintain acceptable comfort conditions.

As in the Pacific buildings, many of the buildings that we visited had modifications made in an attempt to improve comfort conditions. Even still, they were not totally successful.

A number of the buildings that we visited required both temperature and humidity control. These buildings included air crew training facilities and missile maintenance facilities. These buildings were unable to maintain a reasonable degree of control over both the temperature and humidity primarily because the type of air conditioning system selected was unable to be sufficiently responsive to the nature and magnitude of the cooling load in order to provide control over temperature and humidity. In addition, these buildings suffered from maintenance problems, oversizing of air conditioning and control systems that were too sophisticated thus leading to loss of calibration, abandonment and tampering.

TABLE 3-1  
ITEMS NOTED DURING  
FIELD INVESTIGATION

Problems	CHS		New Orleans		Corry		NAS-PNS		NAS-PNS	
	Hosp BEQ		BEQ-WB		BEQ-WB		3248		3468-70	
1. Exterior Surface Condensation										
A. Walls				X						
B. Projections (Floors)										
C. Columns										
D. Interior Corners										
E. Orientation										
F. Air Flow										
G. Clear Sky Radiation										
H. Building Mass										
2. Vapor Flow Into Buildings										
A. Through Materials	X						X	X		
B. Open Windows and Doors							X	X		
C. Exhaust Systems										
D. Ventilation Air	X									
E. Infiltration	X						X			X
3. Condensation In Building Materials										
4. Inability to Dehumidify										
A. Ceiling Tiles	X						X	X		X
B. Walls	X						X	X		
C. Closets	X									
D. Saturated Cooled Air							X			
E. Chilled Water Temperature	X					X	X	X		X
F. Lower Room Temperatures	X						X			
G. Aggravates 1,2,3 & 5										
H. Fan Coil Units	X						X			
5. Interior Water										
A. Wet Coils										
B. Drain Pans	X						X			X
C. Drain Pan Overflow	X						X			X
D. Pipe Insulation	X						X			X
E. Diffusers + Fan Coil Units	X						X			
F. Showers										
G. Laundry										
H. Walls, Ceilings and Floors	X									X

# ASHRAE PSYCHROMETRIC CHART NO. 1

NORMAL TEMPERATURE  
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY  
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**CHARLESTON  
HOSPITAL BEQ**



**CHILLED  
WATER  
TEMPERATURE  
53F SUPPLY  
60F RETURN**

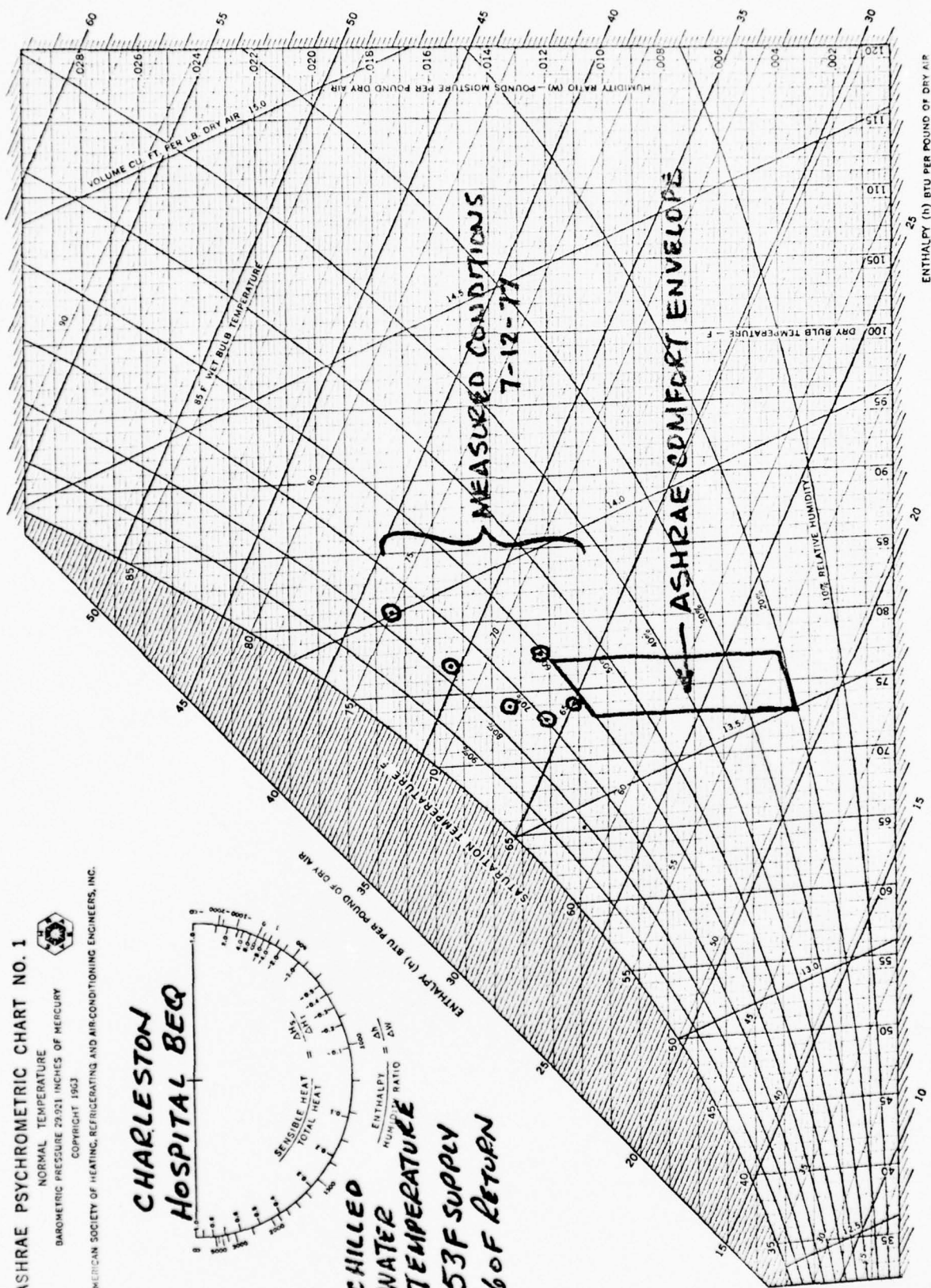


FIGURE 3-1

# ASHRAE PSYCHROMETRIC CHART NO. 1

NORMAL TEMPERATURE  
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY  
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## NEW ORLEANS COMMISSARY

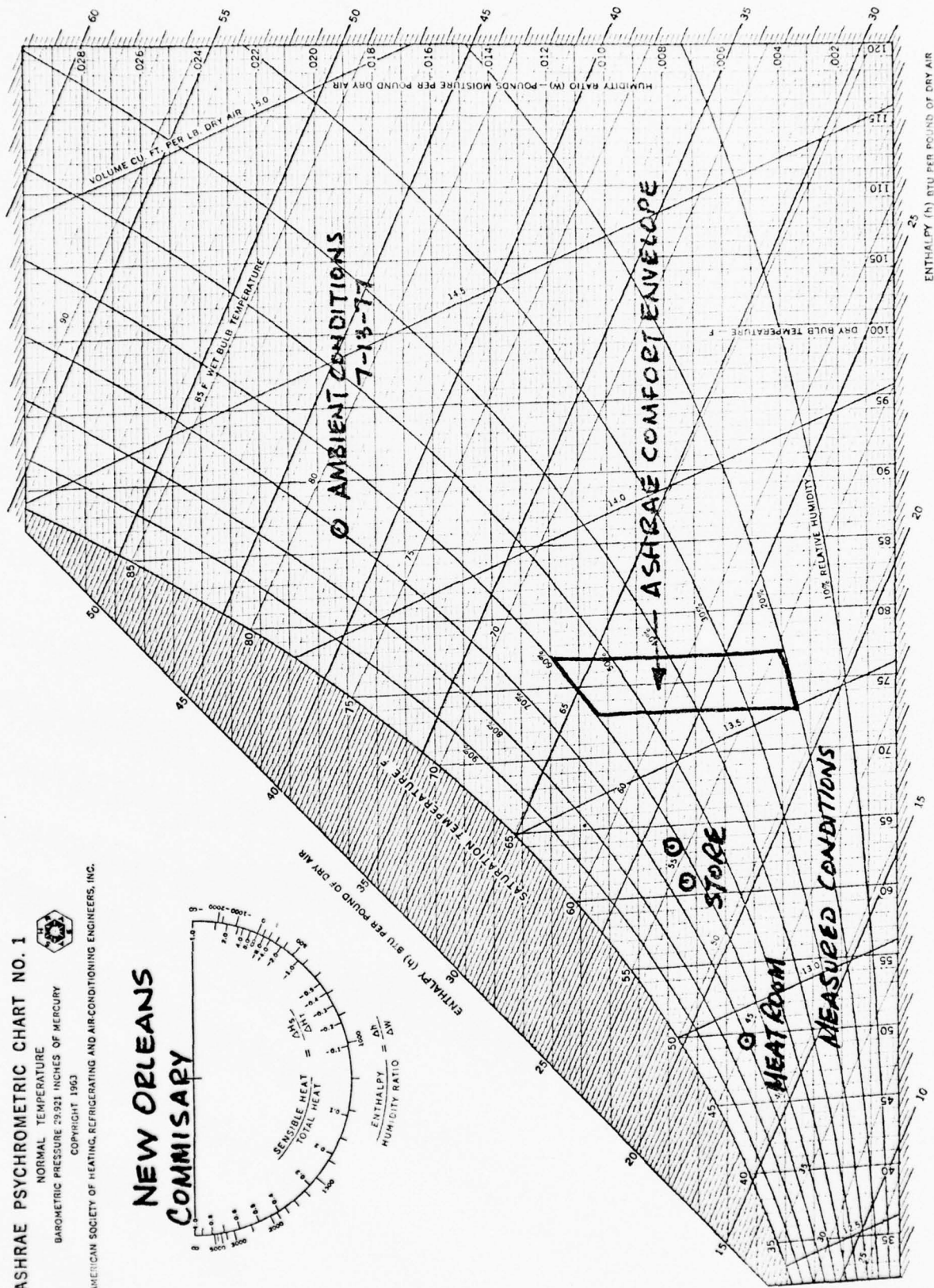
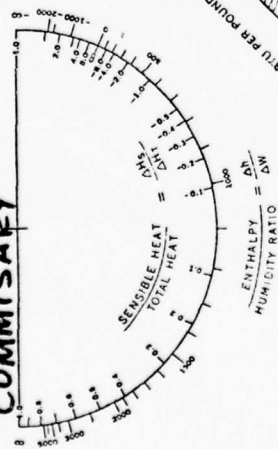


FIGURE 3-2

# ASHRAE PSYCHROMETRIC CHART NO. 1

NORMAL TEMPERATURE

BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY

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**NEW ORLEANS  
BEQ**

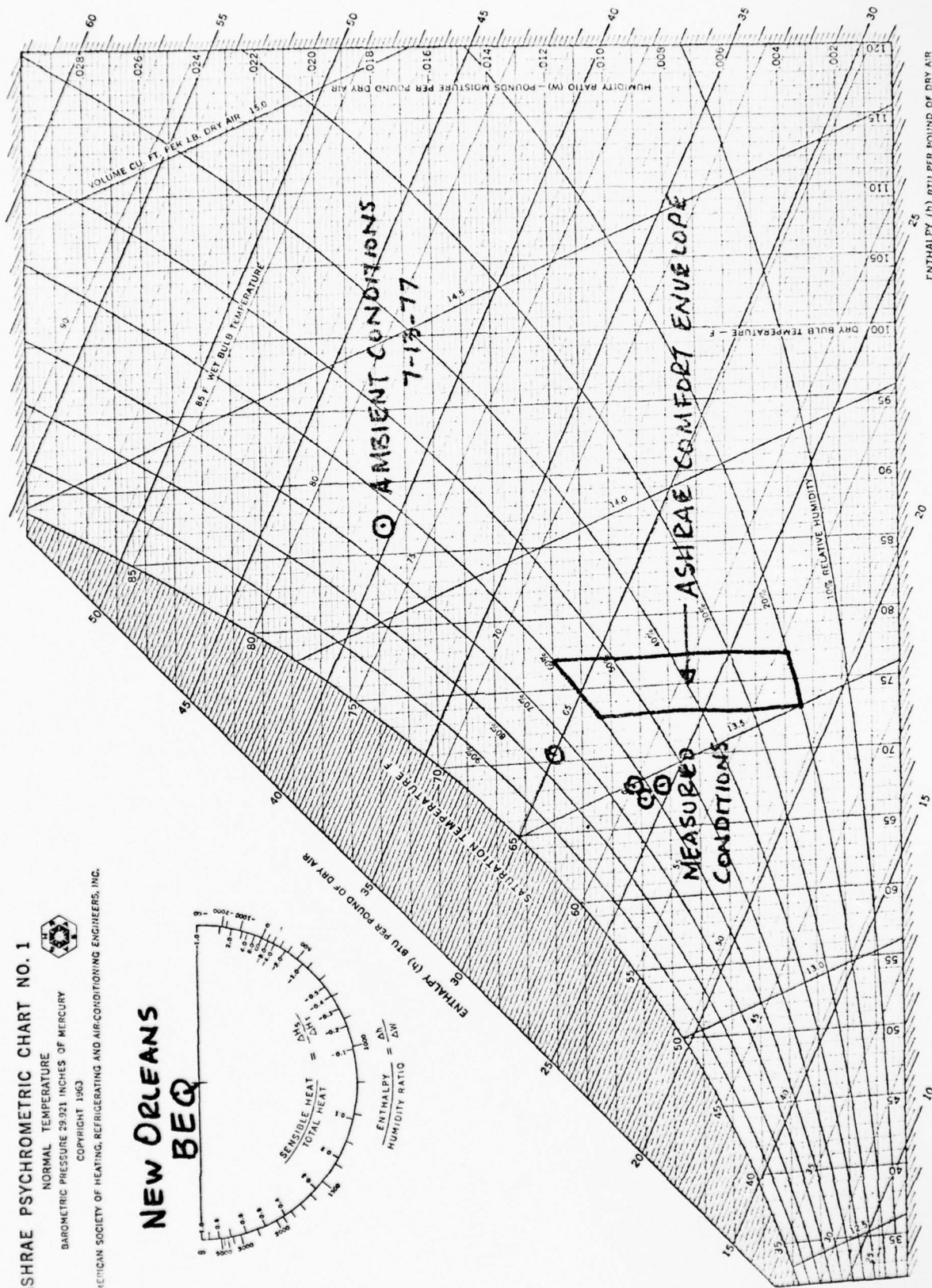
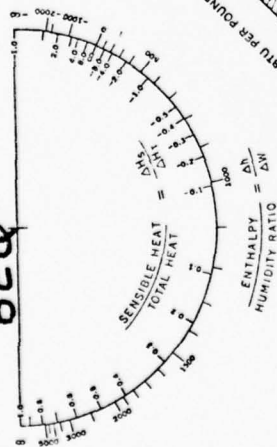


FIGURE 3-3

# ASHRAE PSYCHROMETRIC CHART NO. 1



NORMAL TEMPERATURE  
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY

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**PENSA COLA  
BEQ 3468**

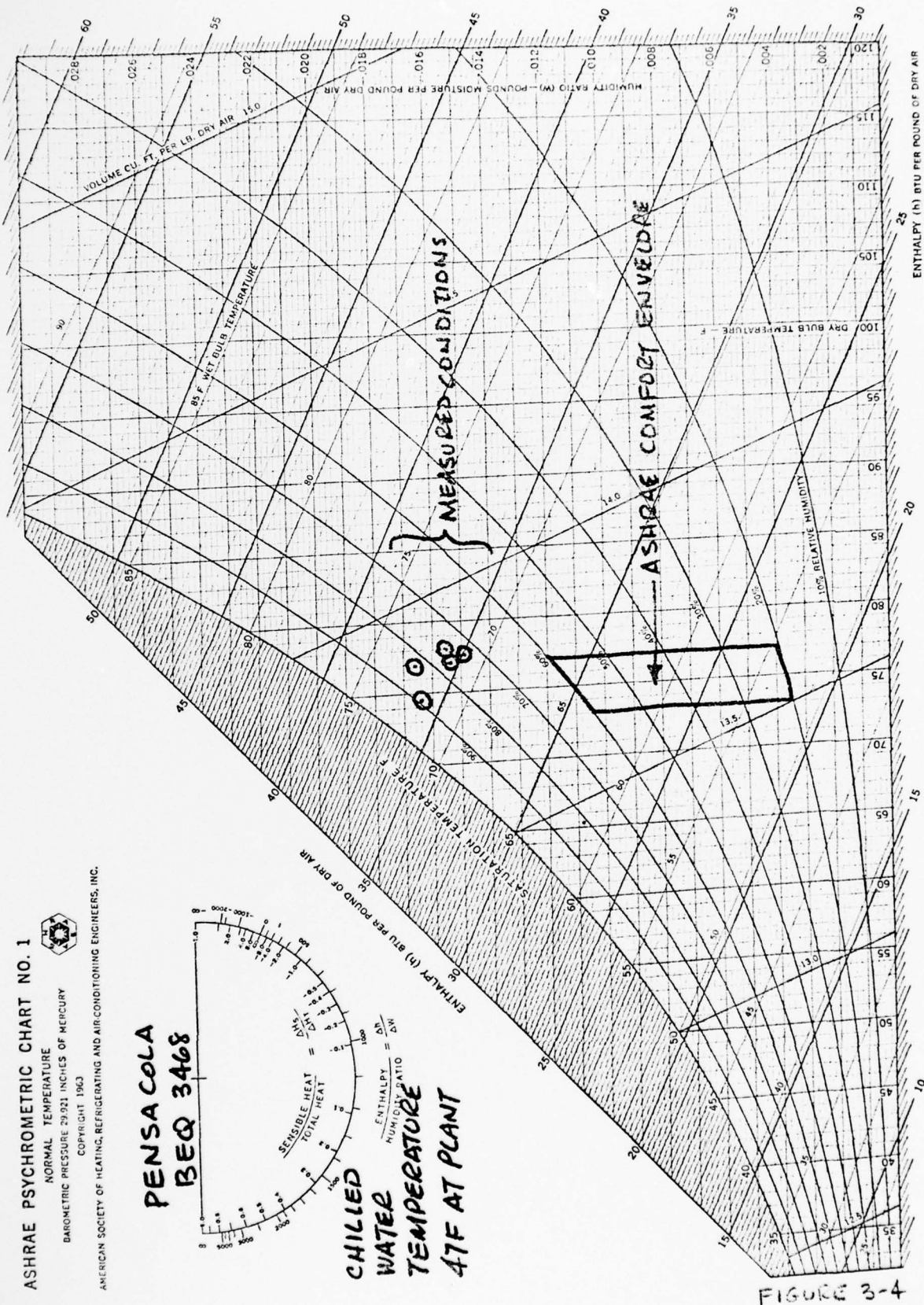
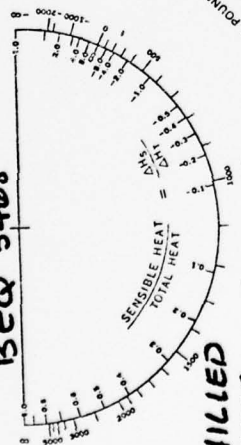


FIGURE 3-4

CHAPTER 4  
WEATHER ANALYSIS

Purpose

The purpose of this part of the work is to obtain and analyze weather data from four locations which experience humid conditions. Those locations are Cubi Point in the Republic of the Philippines, Agana, Guam, Barbers Point, Hawaii and Diego Garcia, Indian Ocean.

Weather data for these locations was obtained, processed and analyzed by computer to determine the extent and severity of the humidity.

Method

Hour by hour weather data for a one year period was obtained from the Naval Weather Service Detachment in Asheville, North Carolina in cooperation with the U.S. Air Force Environmental Technical Applications Center, Scott Air Force Base, Illinois. This data was then computer processed to evaluate maxima, minima and averages for those weather factors that influence air conditioning.

Results

The results of the computer analysis are shown on pages 4A-1 through 4D-10.

For each location the weather summary shows the month by month maximum and minimum dry bulb and dew point temperatures, the average dry bulb, dew point and wet bulb temperatures along with average cloud cover and cooling degree days to a 65F base.

Month by month cooling degree hours are also shown and in some instances the data was further broken down into certain periods of the day, namely the day time hours of 6 A.M. through 5 P.M. and the night time hours of midnight through 5 A.M. plus 6 P.M. through midnight.

Dry bulb temperature frequencies are shown on a month by month basis in five degree bins along with the average dew point temperature for each bin. Dew point temperature frequencies are shown in five degree bins coincident with dry bulb temperature bins.

Finally, cloud cover frequency is shown on a monthly basis by tenths.

#### Analysis

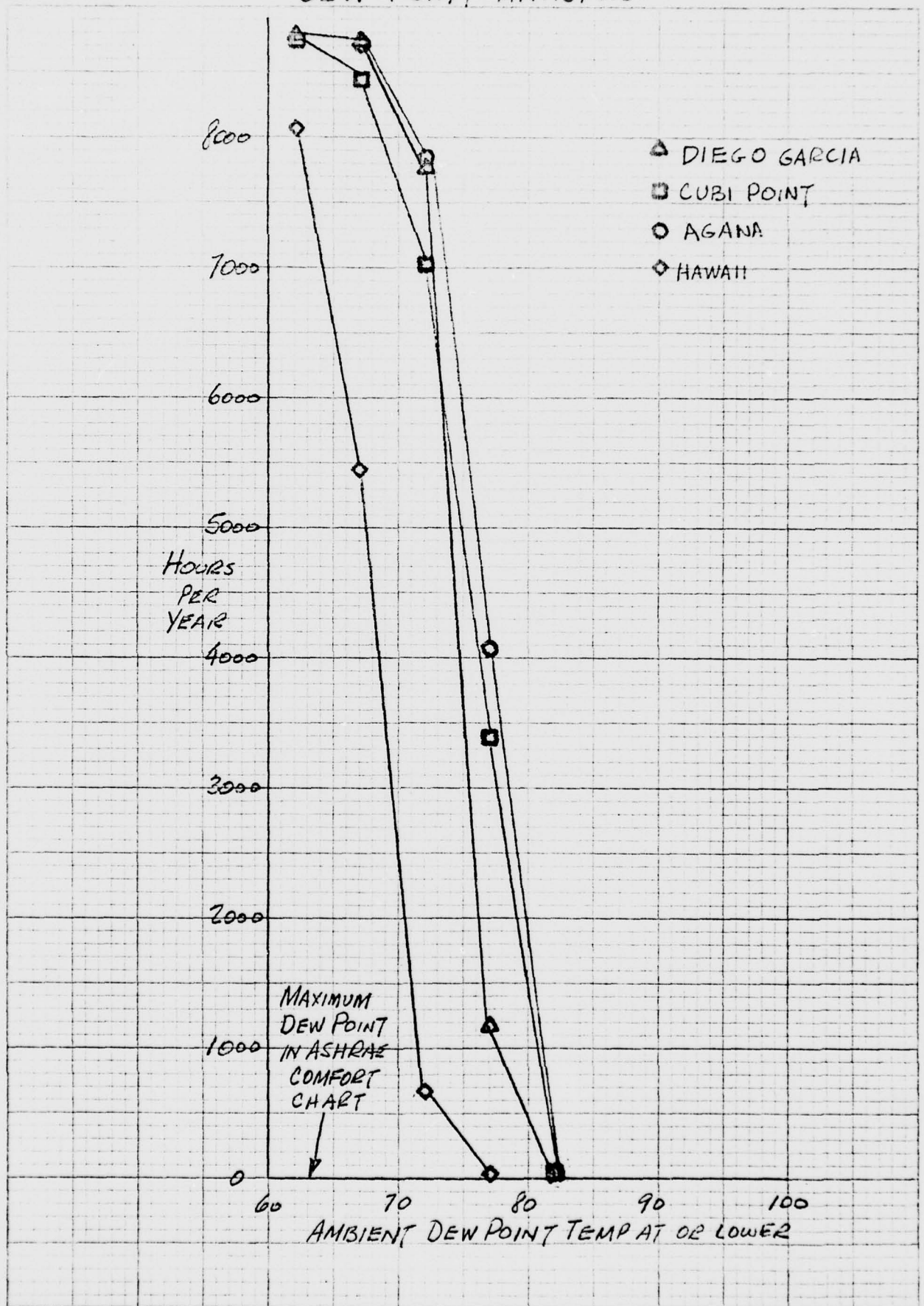
Table 4-1 shows a summary of the results and a comparison with the Navy design criteria. Figure 4-1 shows a frequency analysis of the dew point temperatures for each of the locations. It can be seen that almost 100% of the hours in the year at all locations have dew points above the maximum dew point shown in the ASHRAE Comfort Chart. This would indicate the need for full time dehumidification, if not full time cooling.

The weather in Hawaii is the least severe of those locations evaluated, while the weather in Guam is the most severe. In Guam, the Philippines and Diego Garcia there are more than 7,000 hours per year with ambient dew point temperatures in excess of 72F.

TABLE 4-1  
WEATHER SUMMARY

	STATIONS			
	CUBI POINT R.P.	AGANA GUAM	BARBERS POINT HI.	DIEGO GARCIA I.O.
Maximum Dry Bulb	97	89	88	90
Minimum Dry Bulb	69	70	58	68
Maximum Dew Point	82	80	77	83
Minimum Dew Point	59	47	49	62
Heating Degree Days	0	0	0	0
Cooling Degree Days	6240	5692	3945	5405
NAVFAC P-89				
Dry Bulb-1%	95	89	87	90
Dry Bulb-2½%	93	88	86	89
Dry Bulb-5%	91	87	85	88
Dry Bulb-99%	69	72	60	71
Dry Bulb-97½%	70	73	62	72
Wet Bulb-1%	81	80	77	81
Wet Bulb-2½%	80	80	76	81
Wet Bulb-5%	80	79	75	80
Cooling Degree Days	6285	5865	3929	5854

# DEW POINT ANALYSIS



WEATHER SUMMARY PROGRAM - WAV (Version 3)  
(EXECUTED AS WAV3)

Degree Day Summary	10	11	12	13	14	15	16
for cooling (10)							
Ref. temp.							
Ref. temp. (9)							
Key (8)							
Avg. Day (7)							
CC Table (6)							
DP WAS Table (5)							
Combine Periods (4)							
Duration							
Hrs.							
Middle Period (3)							
Begin Hk. No.							
Solar key (1)							
Table Key (2)							

20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80																			
CUBI POINT NAS																				PHILIPPINES																				1950																																							

- (1) Solar data key:  
0 = Weather tape of file begins with either 13 or 24 hour solar  
1 = Weather tape of file contains no solar data
- (2) Tape of file format key:  
0 = BCD card image data  
1 = NTRAN data (for use at UCC)
- Input Tape on LU1
- (3) If entries are made here, the 5-deg band temperature frequency occurrence will be divided in to three time slots, with the middle time slot beginning with the hour number (midnight = 1, 1 AM = 2, etc.) shown in cols. 3-4

### Input Tape on LUI

- (3) If entries are made here, the 5-day band temperature frequency occurrence will be divided in to three time slots, with the middle time slot beginning with the hour number (midnight = 1, 1 AM = 2, etc.) shown in cols. 3-4 and lasting the number of hours shown in cols. 5-6. For instance, entries of 9 and 8 respectively would have the middle period begin with hour 9 (8 AM) and extend 8 hours (up to, but not including, 4 PM).
- (4) Enter "1" if the two time periods before and after the middle time period are to be added together.
- (5) Enter "1" if a printout of dew point temperature frequency occurrence is desired. Enter "2" if a printout of wet bulb temperature frequency occurrence is desired.

# DATA FOR CUBI POINT NAS PHILIPPINES 1960

## MAX, MIN, AND AVG MONTHLY TEMPERATURES

MONTH	MAX			MIN			MAX			MIN			AVG			AVG			HEATING			COOLING						
	DRY	DAY	HLR	DRY	DAY	HLR	DEW	PNT	DAY	HR	DEW	PNT	DAY	HR	DRY	RLR	DEW	PNT	WET	RLR	CLD	CVR	DAYS	DEG	DAYS	DEG	DAYS	DEG
JAN	92	10	16	70	16	8	76	10	21	59	15	20	79.6	68.6	71.8	4.2	0	486										
FEB	91	9	16	70	4	5	78	28	20	60	5	6	80.1	68.7	72.0	5.3	0	463										
MAR	95	29	16	72	1	6	77	20	22	59	7	15	82.0	70.4	73.7	2.1	0	568										
APR	97	14	16	74	24	5	80	29	17	67	8	12	83.4	73.4	76.0	4.4	0	585										
MAY	95	5	15	74	28	15	80	29	11	67	12	15	83.6	74.4	76.8	5.2	0	613										
JUN	92	22	13	70	28	11	81	10	16	69	28	11	81.2	76.1	77.3	7.2	0	503										
JUL	94	10	16	74	1	4	81	4	17	71	12	15	81.6	75.4	77.0	6.8	0	550										
AUG	90	31	13	74	5	7	80	12	15	72	9	2	80.2	76.7	77.5	8.2	0	483										
SEP	90	1	14	73	29	4	82	11	15	69	6	16	79.4	75.0	76.1	7.8	0	479										
OCT	91	23	13	73	22	6	80	18	13	64	30	5	80.1	73.9	75.5	5.9	0	499										
NOV	92	12	13	73	3	5	79	16	16	59	30	8	81.1	71.1	73.9	4.2	0	524										
DEC	91	12	14	69	17	5	77	18	16	59	5	13	79.3	69.1	72.1	4.5	0	487										
TOTAL																										0	6240	

DATA FOR CUBI POINT NAS PHILIPPINES 1960

DEGREE-HOUR SUMMARY

REFERENCE TEMPERATURE FOR HEATING IS 65 F

REFERENCE TEMPERATURE FOR COOLING IS 65 F

MONTH	12 M THRU 5AM AND				6AM THRU 5PM THRU			
	HEATING	COOLING	HEATING	COOLING	HEATING	COOLING	HEATING	COOLING
JAN	0	10830	0	4409	0	6421	0	0
FEB	0	10123	0	4188	0	5935	0	0
MAR	0	12662	0	5300	0	7362	0	0
APR	0	13220	0	5658	0	7562	0	0
MAY	0	13825	0	6011	0	7814	0	0
JUN	0	11686	0	5306	0	6380	0	0
JUL	0	12315	0	5262	0	7053	0	0
AUG	0	11291	0	5260	0	6027	0	0
SEP	0	10387	0	4475	0	5912	0	0
OCT	0	11234	0	4855	0	6379	0	0
NOV	0	11604	0	4737	0	6867	0	0
DEC	0	10610	0	4328	0	6286	0	0
ANN	0	139791	0	54793	0	79998	0	0

DATA FOR CUBI POINT NAS PHILIPPINES 1960

DRY BULB TEMPERATURE FREQUENCY OCCURRENCE FOR THE TIME PERIOD 1 P M THRU 11 PM

DRY BULB RANGE	*..JAN..*		*..FEB..*		*..MAR..*		*..APR..*		*..MAY..*		*..JUN..*		*..JUL..*		*..AUG..*		*..SEP..*		*..OCT..*		*..NOV..*		*..DEC..*		*..ANNUAL..*	
	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT
105 UP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100/104	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95/99	0	0	0	0	1	67	7	69	5	71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	69
90/94	11	69	16	69	77	68	99	72	109	73	7	75	43	75	2	75	5	75	8	72	15	72	4	71	396	72
85/89	153	68	174	69	194	71	175	74	183	75	161	77	171	76	68	77	111	76	144	74	201	71	129	70	1824	73
80/84	172	69	173	69	187	72	246	74	291	75	276	77	230	76	359	77	172	76	198	75	171	72	214	70	2689	74
75/79	290	69	275	69	249	70	190	73	155	74	266	75	295	75	310	76	416	74	371	74	308	71	251	70	3376	73
70/74	118	68	74	66	36	68	3	71	1	74	10	73	5	73	5	74	16	73	23	72	25	70	142	66	458	68
65/69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	62	0
60/64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55/59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50/54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40/44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35/39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30/34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25/29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20/24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15/19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0/4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-5/-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-10/-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-15/-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-20/-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-25/-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-30/-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-35/-31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-36/DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

## DATA FOR CUBZ POINT NAS PHILIPPINES 1960

DRY BULB TEMPERATURE FREQUENCY OCCURRENCE FOR THE TIME PERIOD 12 M THRU 5AM AND 6PM THRU 11PM

*..JAN...*		*..FEB...*		*..MAR...*		*..APR...*		*..MAY...*		*..JUN...*		*..JUL...*		*..AUG...*		*..SEP...*		*..OCT...*		*..NOV...*		*..DEC...*		*..ANNUAL...*		
NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	
HRS	DPT	HRS	DPT	HRS	DPT	HRS	DPT	HRS	DPT	HRS	DPT	HRS	DPT	HRS	DPT	HRS	DPT	HRS	DPT	HRS	DPT	HRS	DPT	HRS	DPT	
105	UP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
104	104	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
95	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
94	94	0	0	0	0	1	65	1	69	5	74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
95	89	5	68	5	69	30	72	47	75	52	76	23	77	23	77	5	76	4	76	0	0	3	72	0	0	197
84	84	71	70	75	71	135	72	173	74	212	75	153	76	123	76	171	77	59	76	104	75	98	72	76	72	1450
79	79	208	69	206	69	184	71	137	73	103	74	181	75	222	75	193	76	283	75	252	74	239	71	192	70	2400
74	74	88	68	50	65	22	68	2	71	0	0	3	74	4	73	3	74	14	72	16	72	20	69	102	66	324
65	69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	63	2	63
64	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
55	59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
54	54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
45	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
44	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
35	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
34	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
25	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
24	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
15	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
14	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
5	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-5	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-14	-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-15	-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-20	-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-25	-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-35	-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-35	-31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-36	-34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

DATA FOR CURI POINT NAS PHILIPPINES 1960

DRY BULB TEMPERATURE FREQUENCY OCCURRENCE FOR THE TIME PERIOD 6 AM THRU 5 PM

DRY BULB RANGE	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		ANNUAL	
	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG
105 UP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
105/104	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95/99	0	0	0	0	1	67	7	69	5	71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	69
90/94	11	69	16	69	76	68	98	72	104	73	7	75	43	75	2	75	5	75	8	72	15	72	4	71	349	72
85/89	148	68	129	70	144	71	128	74	131	75	138	77	148	76	63	77	107	76	144	74	198	71	129	70	1627	73
80/84	101	69	98	68	52	70	73	74	79	75	123	77	107	76	188	77	113	76	98	75	73	71	138	69	1219	73
75/79	82	68	69	68	65	70	53	73	52	74	85	75	73	75	117	76	133	74	119	73	62	70	59	68	976	72
70/74	30	68	24	66	14	68	1	71	1	74	7	72	1	73	2	74	2	73	7	71	5	71	40	67	114	68
65/69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	62	0
60/64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55/59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50/54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40/44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35/39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30/34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25/29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20/24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15/19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0/4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-5/-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-10/-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-15/-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-20/-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-25/-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-30/-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-35/-31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-36 DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

DATA FOR CURI POINT NAS PHILIPPINES 1960

DEW PNT TEMPERATURE FREQUENCY OCCURRENCE FOR THE TIME PERIOD 17 M THRU 11PM

		DEW PNT TEMPERATURE RANGES																																											
DRY BLR		-36	-35	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105														
RANGE		04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33														
105	UP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
100	104	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
95	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
90	94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
85	89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
80	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
75	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
70	74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
65	69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
60	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
55	59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
50	54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
45	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
40	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
35	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
30	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
25	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
20	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
15	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
10	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
5	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
-5	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
-10	-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
-15	-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
-20	-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
-25	-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
-30	-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
-35	-31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
-36	04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														

# DATA FOR CUBI POINT NAS PHILIPPINES 1960

DEW PNT		TEMPERATURE FREQUENCY OCCURRENCE FOR THE TIME PERIOD																												1 P M		THRU		5 AM		AND		6 PM		THRU		11 PM																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
		DEW PNT																												TEMPERATURE RANGES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
DRY BLB		-34 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
RANGE		DN -31 -26 -21 -16 -11 -6 -1 4 9 14 19 24 29 34 39 44 49 54 59 64 69 74 79 84 89 94 99 104 UP																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
105	UP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

DEW PNT TEMPERATURE FREQUENCY OCCURRENCE FOR THE TIME PERIOD 6AM THRU 5PM

4A-9

DATA FOR CURI POINT NAS PHILIPPINES 1960

CLOUD COVER FREQUENCY OCCURRENCE

	*..JAN....*	*..FEB....*	*..MAR....*	*..APR....*	*..MAY....*	*..JUN....*	*..JUL....*	*..AUG....*	*..SEP....*	*..OCT....*	*..NOV....*	*..DEC....*	*..ANNUAL.*
10 TENTHS	43	47	4	50	86	244	179	425	271	163	14	23	1549
9 TENTHS	63	85	4	34	45	66	92	59	101	54	35	57	695
8 TENTHS	61	72	16	51	69	80	98	52	85	73	52	91	800
7 TENTHS	49	79	20	72	66	63	83	47	71	66	56	73	745
6 TENTHS	50	61	29	47	61	50	61	33	50	66	84	51	643
5 TENTHS	60	50	35	73	80	61	37	15	39	55	67	43	615
4 TENTHS	55	56	64	89	106	60	60	23	38	54	82	77	764
3 TENTHS	72	61	92	92	76	50	48	33	31	54	91	94	794
2 TENTHS	97	51	104	71	70	27	48	34	27	74	98	94	795
1 TENTHS	77	63	154	63	59	12	25	21	7	57	97	95	730
0 TENTHS	117	47	222	78	26	7	13	2	0	28	44	46	630



# DATA FOR AGANA FWC GUAM 1958

## MAX, MIN, AND AVG MONTHLY TEMPERATURES

MONTH	MAX DRY				MIN DRY				MAX DEW				MIN DEW				AVG DRY				AVG DEW				AVG WET				HEATING				COOLING			
	RLR	DAY	HR	HR	RLR	DAY	HR	HR	PNT	DAY	HR	HR	PNT	DAY	HR	HR	RLR	RLR	RLR	HR	PNT	PNT	HR	HR	RLR	RLR	RLR	AVG CLD	DEG	DAYS	DEG	DAYS	DEG	DAYS		
JAN	87	8	15	72	5	6	76	8	17	62	2	4	70.5	72.8	5.7	0	440																			
FEB	87	11	16	73	1	2	76	3	21	63	1	15	70.2	72.5	5.4	0	395																			
MAR	88	15	15	73	4	6	76	22	14	53	2	13	69.6	72.4	5.2	0	471																			
APR	87	7	13	72	28	8	77	13	11	60	1	7	72.1	74.2	5.6	0	468																			
MAY	86	2	15	74	30	8	78	28	22	68	4	18	73.5	75.3	6.2	0	495																			
JUN	87	2	17	70	14	6	78	8	11	68	1	7	74.8	76.2	6.4	0	470																			
JUL	89	11	13	72	16	6	80	3	16	71	2	6	75.3	76.5	6.8	0	489																			
AUG	88	6	17	73	25	1	80	10	14	71	3	13	75.7	77.0	6.8	0	513																			
SEP	88	14	17	73	8	20	79	2	15	72	1	21	75.9	77.0	7.5	0	484																			
OCT	88	12	15	73	23	8	79	6	16	47	3	16	75.9	77.1	6.7	0	513																			
NOV	87	3	11	75	2	1	79	2	17	69	2	8	75.6	76.8	6.2	0	486																			
DEC	87	13	15	72	16	4	79	1	15	68	1	2	73.9	75.0	5.2	0	468																			
TOTAL																	0 5692																			

DATA FOR AGANA S.W. GUAM 1950

DEGREE-HOUR SUMMARY

REFERENCE TEMPERATURE FOR HEATING IS 65 F

REFERENCE TEMPERATURE FOR COOLING IS 65 F

MONTH	12 M THRU 11PM				THRU				THRU			
	HEATING	COOLING	HEATING	COOLING	HEATING	COOLING	HEATING	COOLING	HEATING	COOLING	HEATING	COOLING
JAN	0	9972	0	0	0	0	0	0	0	0	0	0
FEB	0	8901	0	0	0	0	0	0	0	0	0	0
MAR	0	10397	0	0	0	0	0	0	0	0	0	0
APR	0	10607	0	0	0	0	0	0	0	0	0	0
MAY	0	11365	0	0	0	0	0	0	0	0	0	0
JUN	0	10865	0	0	0	0	0	0	0	0	0	0
JUL	0	11291	0	0	0	0	0	0	0	0	0	0
AUG	0	11875	0	0	0	0	0	0	0	0	0	0
SEP	0	11013	0	0	0	0	0	0	0	0	0	0
OCT	0	11840	0	0	0	0	0	0	0	0	0	0
NOV	0	11156	0	0	0	0	0	0	0	0	0	0
DEC	0	10793	0	0	0	0	0	0	0	0	0	0
ANN	0	130075	0	0	0	0	0	0	0	0	0	0

DATA FOR AGANA FWC GUAM 1958

DRY BULB TEMPERATURE FREQUENCY OCCURRENCE FOR THE TIME PERIOD 1 P M THRU 11 PM

		*..JAN..*		*..FEB..*		*..MAR..*		*..APR..*		*..MAY..*		*..JUN..*		*..JUL..*		*..AUG..*		*..SEP..*		*..OCT..*		*..NOV..*		*..DEC..*		*..ANNUAL..*			
DRY BULB	RANGE	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	HRS DPT	HRS DPT
105	UP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
100	104	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
95	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
90	94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
85	89	5	70	5	73	35	68	47	72	46	73	62	74	79	74	138	76	94	77	131	77	69	76	25	75	736	75	736	75
80	84	233	70	222	70	260	69	260	72	329	74	288	75	279	74	318	76	259	76	312	76	341	76	288	74	3389	74	3389	74
75	79	472	71	395	70	422	70	405	72	368	73	360	75	378	75	282	75	358	75	297	75	310	75	421	73	4663	73	4663	73
70	74	34	70	50	69	27	69	8	70	1	73	10	72	8	72	6	74	9	73	4	73	0	0	10	72	167	70	167	70
65	69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
60	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
55	59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
50	54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
45	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
40	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
35	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
30	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
25	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
15	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
10	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
5	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-5	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-10	-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-15	-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-20	-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-25	-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-30	-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-35	-31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-36	DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

DEW POINT TEMPERATURE FREQUENCY OCCURRENCE FOR THE TIME PERIOD 12 M THRU 11PM

4B-5

DATA FOR AGANA FWC GUAM 1958

CLOUD COVER FREQUENCY OCCURRENCE

	*..JAN...*	*..FEB...*	*..MAR...*	*..APR...*	*..MAY...*	*..JUN...*	*..JUL...*	*..AUG...*	*..SEP...*	*..OCT...*	*..NOV...*	*..DEC...*	*..ANNUAL...*
10 TENTHS	72	42	30	29	74	91	133	124	192	106	71	49	1017
9 TENTHS	51	31	38	53	49	69	82	108	109	107	78	57	832
8 TENTHS	98	77	83	82	104	84	134	116	125	95	89	68	1155
7 TENTHS	93	73	70	88	111	110	87	84	68	106	84	61	1035
6 TENTHS	69	83	78	96	105	115	84	77	74	80	125	79	1065
5 TENTHS	67	101	124	108	105	81	74	74	48	110	84	95	1073
4 TENTHS	113	120	121	124	93	79	62	65	53	67	68	119	1084
3 TENTHS	93	66	113	102	70	58	41	59	32	48	85	89	856
2 TENTHS	58	52	68	32	26	28	32	32	19	25	33	102	507
1 TENTHS	22	22	17	6	5	5	14	1	0	0	3	23	118
0 TENTHS	8	5	2	0	0	0	1	0	0	0	0	2	18

ross f. meriwether & associates, inc.  
1600 n. e. loop 410; 512 824-5302  
san antonio, texas 78209

# WEATHER SUMMARY PROGRAM - WAV (Version 3) (EXECUTED AS WAV3)

## CARD 1: INPUT KEYS AND LABEL

Degree Day Summary		Ref. temp. for heating (9)		Ref. temp. for cooling (10)		Key (8)		Avg. Day (7)		CC Table (6)		DP WXB Table (5)		Combine Periods (4)		Hrs.		Middle Period (3)		Begin Hr. No.		Tape Key (2)		Solar Key (1)																																																							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

LABEL

## (1) Solar data key:

- 0 = Weather tape of file begins with either 13 or 24 hour solar
- 1 = Weather tape of file contains no solar data

## (2) Tape of file format key:

- 0 = BCD card image data
- 1 = NTRAN data (for use at UCC)

## Input Tape on LU1

- (3) If entries are made here, the 5-deg band temperature frequency occurrence will be divided in to three time slots, with the middle time slot beginning with the hour number (midnight = 1, 1 AM = 2, etc.) shown in cols. 3-4 and lasting the number of hours shown in cols. 5-6. For instance, entries of 9 and 8 respectively would have the middle period begin with hour 9 (8 AM) and extend 8 hours (up to, but not including, 4 PM).

- (4) Enter "1" if the two time periods before and after the middle time period are to be added together.

- (5) Enter "1" if a printout of dew point temperature frequency occurrence is desired. Enter "2" if a printout of wet bulb temperature frequency occurrence is desired.

- (6) Enter "1" if a printout of cloud cover frequency occurrence is desired.

- (7) Enter "1" if a printout of average daily dry bulb, dew point, wet bulb, and cloud cover is desired.

## (8) Degree day printout key

- 0 = degree "day" basis
- 1 = degree "hour" basis
- 2 = both degree "days" and degree "hours"

- (9) If blank, no heating degree days (or hours) will be calculated.

- (10) If blank, no cooling degree days (or hours) will be calculated.

# DATA FOR BARBERS POINT NAS HAWAII 1960

## MAX, MIN, AND AVG MONTHLY TEMPERATURES

MONTH	MAX				MIN				MAX				MIN				AVG				AVG				HEATING				COOLING			
	DAY	HR	DAY	HR	DAY	HR	DAY	HR	PNT	DAY	HR	DAY	HR	PNT	DAY	HR	DAY	HR	PNT	DAY	HR	DAY	HR	DAY	HR	DAY	HR	DAY	HR			
JAN	82	1	15	58	21	7	70	29	14	52	21	6	71.6	62.0	65.3	4.6	0	231														
FEB	81	18	13	58	21	8	71	7	12	49	10	19	71.0	60.4	60.2	4.9	0	186														
MAR	81	8	16	61	13	6	73	6	23	49	12	13	71.9	63.1	66.1	5.2	0	233														
APR	81	2	14	65	6	7	70	1	13	53	7	13	73.2	62.7	66.2	4.3	0	264														
MAY	84	17	14	66	13	1	72	31	13	58	17	14	75.7	65.1	68.5	4.6	0	358														
JUN	85	3	14	70	1	4	74	4	15	61	25	15	77.6	66.4	69.8	4.5	0	393														
JUL	86	25	15	70	3	7	74	27	15	60	15	14	78.2	66.1	69.8	4.4	0	429														
AUG	87	12	15	72	3	7	75	11	15	62	3	15	78.7	67.2	70.7	5.0	0	403														
SEP	86	11	16	70	3	5	77	29	14	61	2	15	77.9	68.1	71.0	4.8	0	409														
OCT	88	18	12	67	15	6	76	18	19	62	30	14	77.4	68.4	71.1	4.8	0	409														
NOV	84	2	14	65	6	7	73	10	15	56	29	24	75.0	65.5	68.5	4.3	0	324														
DEC	83	10	16	64	8	6	74	4	15	52	24	3	72.8	64.8	67.4	4.4	0	266														
TOTAL																		0	3925													

DATA FOR BARBERS POINT NAS HAWAII 1960

DEGREE-MONTH SUMMARY

REFERENCE TEMPERATURE FOR HEATING IS 65 F

REFERENCE TEMPERATURE FOR COOLING IS 65 F

MONTH	12 M THRU 11PM				THRU			
	HEATING	COOLING	HEATING	COOLING	HEATING	COOLING	HEATING	COOLING
JAN	177	5070	0	0	0	0	0	0
FEB	144	4144	0	0	0	0	0	0
MAR	34	5184	0	0	0	0	0	0
APR	0	5894	0	0	0	0	0	0
MAY	0	7948	0	0	0	0	0	0
JUN	0	9061	0	0	0	0	0	0
JUL	0	9802	0	0	0	0	0	0
AUG	0	10156	0	0	0	0	0	0
SEP	0	9294	0	0	0	0	0	0
OCT	0	9235	0	0	0	0	0	0
NOV	0	7197	0	0	0	0	0	0
DEC	2	5811	0	0	0	0	0	0
ANN	357	88796	0	0	0	0	0	0

DATA FOR BARBERS POINT NAS HAWAII 1960

DRY BULB TEMPERATURE FREQUENCY OCCURRENCE FOR THE TIME PERIOD 12 M THRU 11PM

DRY BULB RANGE	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		ANNUAL	
	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG	NO.	AVG
105/104	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95/94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85/84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75/74	216	63	156	64	200	65	240	63	241	66	218	67	291	66	335	68	271	69	200	69	217	65	222	66	2897	66
70/74	304	63	230	61	265	64	275	63	312	65	216	66	161	65	99	66	176	67	197	67	336	66	289	65	2848	65
65/64	171	61	199	59	258	61	145	61	18	63	0	0	0	0	0	0	0	0	7	65	34	62	180	63	1014	61
60/64	36	56	65	54	20	57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	60	123	55
55/54	10	53	2	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	53
50/54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45/44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40/44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35/34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30/34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25/24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20/24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15/14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0/4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-5/-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-10/-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-15/-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-20/-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-25/-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-30/-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-35/-31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-36 DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

## DEW PNT TEMPERATURE FREQUENCY OCCURRENCE FOR THE TIME PERIOD 12 M THRU 11PM

4C-15

DATA FOR BARRERS POINT NAS HAWAII 1960

CLOUD COVER FREQUENCY OCCURRENCE

	*..JAN..*	*..FEB..*	*..MAR..*	*..APR..*	*..MAY..*	*..JUN..*	*..JUL..*	*..AUG..*	*..SEP..*	*..OCT..*	*..NOV..*	*..DEC..*	*..ANNUAL..*
10 TENTHS	27	42	76	7	34	12	7	28	19	45	6	49	352
9 TENTHS	48	43	66	13	43	32	27	44	49	31	13	25	434
8 TENTHS	69	61	62	59	48	60	55	69	48	61	29	62	683
7 TENTHS	74	73	79	66	72	57	42	71	57	73	75	65	809
6 TENTHS	60	61	74	76	77	87	73	80	97	60	68	54	876
5 TENTHS	79	60	54	86	83	85	120	88	92	92	98	75	1012
4 TENTHS	80	73	69	97	76	104	116	101	100	93	124	77	1110
3 TENTHS	100	109	74	146	110	115	148	119	101	110	171	95	1398
2 TENTHS	99	84	99	128	128	94	120	93	112	117	93	83	1250
1 TENTHS	64	53	82	41	68	70	36	41	45	62	38	138	738
0 TENTHS	39	13	9	1	5	4	0	1	0	0	5	21	98



DATA FOR DIEGO GARCIA, PACIFIC OCEAN 1975 STATION 70701

MAX, MIN, AND AVG MONTHLY TEMPERATURES

MONTH	MAX DRY			MIN DRY			MAX DEW			MIN DEW			AVG DRY			AVG DEW			AVG WET			HEATING			COOLING		
	REL	DAY	HR	REL	DAY	HR	PNT	DAY	HR	PNT	DAY	HR	REL	DAY	HR	PNT	REL	DAY	HR	REL	DAY	HR	DEG	DAYS	DEG	DAYS	
JAN	88	12	5	71	22	9	79	14	22	68	6	10	80.1			71.8			74.1			0		0	480		
FEB	89	26	8	73	7	6	81	18	8	68	18	10	80.9			72.5			74.7			0		0	443		
MAR	90	4	4	73	5	17	77	2	4	69	5	19	80.8			73.3			75.3			0		0	508		
APR	88	2	2	72	24	14	77	2	23	66	26	19	79.8			72.2			74.2			0		0	462		
MAY	88	3	2	72	5	10	79	3	4	66	7	17	79.1			71.7			73.7			0		0	455		
JUN	85	1	2	69	21	17	79	1	23	62	20	13	78.2			70.9			73.0			0		0	416		
JUL	85	1	2	69	11	23	76	2	12	64	8	11	77.0			71.0			72.7			0		0	389		
AUG	86	18	4	72	9	14	79	14	2	66	1	11	78.3			72.1			73.8			0		0	442		
SEP	88	3	4	71	25	23	78	1	3	68	10	16	79.3			73.1			74.7			0		0	459		
OCT	85	1	4	68	7	5	76	10	2	66	3	19	77.9			71.1			73.0			0		0	415		
NOV	88	20	4	70	25	20	79	17	4	69	6	1	79.6			74.2			75.6			0		0	453		
DEC	87	22	1	68	12	11	83	27	22	68	12	11	80.4			72.8			74.9			0		0	483		
TOTAL																					0			5405			

DATA FOR DIEGO GARCIA, INDIAN OCEAN JO/S STATION 70701

DEFERRED SUMMARY

REFERENCE TEMPERATURE FOR HEATING IS 65 F

REFERENCE TEMPERATURE FOR COOLING IS 65 F

MONTH	12 M THRU 5AM AND 6PM THRU 11PM				6AM THRU 5PM THRU			
	HEATING	COOLING	HEATING	COOLING	HEATING	COOLING	HEATING	COOLING
JAN	0	11255	0	5417	0	5838	0	0
FEB	0	10672	0	5203	0	5469	0	0
MAR	0	11746	0	5765	0	5981	0	0
APR	0	10622	0	5209	0	5413	0	0
MAY	0	10477	0	5092	0	5385	0	0
JUN	0	9515	0	4689	0	4826	0	0
JUL	0	8937	0	4420	0	4517	0	0
AUG	0	9877	0	4903	0	4974	0	0
SEP	0	10322	0	5136	0	5186	0	0
OCT	0	9586	0	4709	0	4877	0	0
NOV	0	10500	0	5134	0	5366	0	0
DEC	0	11461	0	5782	0	5679	0	0
ANN	0	124970	0	61459	0	63511	0	0

DATA FOR DIEGO GARCIA, INDIAN OCEAN 1975 STATION 70701

DRY BULB TEMPERATURE FREQUENCY OCCURRENCE FOR THE TIME PERIOD 12 M THRU 11PM

DRY BULB RANGE	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		ANNUAL	
	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT	NO. AVG	HRS DPT
105-109	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95-99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85-89	112	73	122	74	136	75	155	76	174	77	215	78	235	79	255	80	274	81	293	82	312	83	331	84	350	85
75-79	378	71	275	72	271	73	364	74	399	75	375	76	456	77	467	78	477	79	487	80	497	81	507	82	517	83
65-69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55-59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45-49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35-39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-5/-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-10/-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-15/-20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-20/-25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-25/-30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-30/-35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-35/-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

## DATA FOR

TABLE 1. DRY BULB TEMPERATURE FREQUENCY OCCURRENCE FOR THE TIME PERIOD 12 M THRU 5AM AND 6PM THRU 11PM

[illegible]

DATA FOR DIEGO GARCIA, INDIAN OCEAN 1975 STATION 70701

DRY BULB TEMPERATURE FREQUENCY OCCURRENCE FOR THE TIME PERIOD 6AM THRU 5PM

DRY BULB RANGE	JAN.		FEB.		MAR.		APR.		MAY		JUN.		JUL.		AUG.		SEP.		OCT.		NOV.		DEC.		ANNUAL	
	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT	NO. AVG. HRS DPT
105 UP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100/104	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95/99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90/94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85/89	63	73	71	74	68	75	40	73	12	74	3	75	0	0	13	74	21	74	2	74	14	75	22	73	329	74
80/84	139	73	138	73	176	73	143	73	164	72	132	72	78	72	106	73	142	73	134	73	158	75	188	73	1698	73
75/79	161	71	122	72	118	73	165	71	172	71	190	70	237	71	231	72	181	73	188	71	188	74	160	73	2113	72
70/74	9	70	5	70	10	72	12	70	24	71	34	69	57	70	22	71	16	72	41	70	0	0	1	73	231	70
65/69	0	0	0	0	0	0	0	0	0	0	1	64	0	0	0	0	0	0	0	7	68	0	0	1	68	9
60/64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55/59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50/54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45/49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40/44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35/39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30/34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25/29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20/24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15/19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0/4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-5/-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-10/-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-15/-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-20/-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-25/-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-30/-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-35/-31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-36 DPT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

DATA FOR DIEGO GARCIA, INDIAN OCEAN 1975 STATION 70701

DEW PNT TEMPERATURE FREQUENCY OCCURRENCE FOR THE TIME PERIOD 12 M THRU 11PM

		DEW PNT TEMPERATURE RANGES																															
DRY HB		-36	-35	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105		
RANGE		DN	-31	-26	-21	-16	-11	-6	-1	4	9	14	19	24	29	34	39	44	49	54	59	64	69	74	79	84	89	94	99	104	UP		
105	UP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
100/104		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
95/ 99		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
90/ 94		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
85/ 89		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
80/ 84		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
75/ 79		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
70/ 74		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
65/ 69		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
60/ 64		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
55/ 59		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
50/ 54		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
45/ 49		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
40/ 44		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
35/ 39		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
30/ 34		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
25/ 29		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
20/ 24		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
15/ 19		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
10/ 14		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
5/ 9		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0/ 4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
-5/ -1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
-10/ -6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
-15/ -11		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
-20/ -16		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
-25/ -21		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
-30/ -26		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
-35/ -31		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
-40/ -34		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

DATA FOR DIEGO GARCIA, INDIAN OCEAN 1975 STATION 70701

NEW POLY TEMPERATURE FREQUENCY OCCURRENCE FOR THE TIME PERIOD 12 M THRU 5AM AND 6PM THRU 11PM

[illegible]

DATA FOR DIEGO GARCIA, INDIAN OCEAN, 1975 STATION 70701

DEW PNT		TEMPERATURE FREQUENCY OCCURRENCE FOR THE TIME PERIOD												6AM		THRU		5PM												
		TEMPERATURE RANGES																												
DRY BULB		-35	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105
RANGE		0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N	0N
105	100/104	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95/99	90/94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85/89	80/84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75/79	70/74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65/69	60/64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55/59	50/54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45/49	40/44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35/39	30/34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25/29	20/24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15/19	10/14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/9	0/4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-5/-1	-10/-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-15/-11	-20/-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-25/-21	-30/-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-35/-31	-40/-36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

DATA FOR DIEGO GARCIA, INDIAN OCEAN 1975 STATION 70701

CLOUD COVER FREQUENCY OCCURRENCE

	*..JAN..*	*..FEB..*	*..MAR..*	*..APR..*	*..MAY..*	*..JUN..*	*..JUL..*	*..AUG..*	*..SEP..*	*..OCT..*	*..NOV..*	*..DEC..*	*..ANNUAL..*
10 TENTHS	75	10	111	57	93	33	153	159	132	87	78	123	1119
9 TENTHS	33	72	45	60	33	36	72	51	66	42	48	60	618
8 TENTHS	54	81	75	78	63	51	108	87	93	54	60	39	843
7 TENTHS	120	42	81	57	51	60	69	54	87	36	69	57	783
6 TENTHS	78	66	102	81	51	69	69	81	63	39	69	51	819
5 TENTHS	93	45	72	75	57	72	48	45	51	36	69	36	699
4 TENTHS	84	99	81	81	102	114	51	78	69	75	96	51	981
3 TENTHS	87	108	75	93	114	147	75	93	69	168	129	93	1251
2 TENTHS	90	102	93	108	93	117	81	66	72	129	81	156	1188
1 TENTHS	21	36	9	27	84	18	18	30	18	57	21	78	417
0 TENTHS	9	3	0	3	3	3	0	0	0	21	0	0	42

CHAPTER 5  
REVIEW OF DESIGN CRITERIA

Purpose

A review was made of the various design publications utilized for the design of air conditioned buildings in humid climates. Since the criteria in these publications relating to air conditioning were developed and applied primarily in the Continental United States, particular attention was paid to those requirements which would influence the performance of air conditioned buildings in humid climates.

Notes on the various requirements and comments are included in this Chapter, while recommendations for changes are included in Chapter 9. See Chapter 8 for Paints, Coatings and Roofing.

Notes

The design publications that were reviewed are shown in Table 5-1. Notation was made of the various requirements and criteria in these publications and are shown on the following pages. In each note the letter refers to the design publication and the number refers to the note number for that publication.

TABLE 5-1

DESIGN PUBLICATIONS REVIEWED

- A. Navy Guide Specifications
- B. Economic Analysis Handbook (NAFAC P-442) June 1975
- C. Technical Guidelines and Criteria for Energy Conservation in Buildings (SOUTHDIVNAFAC 15000) July 1975
- D. Design Guidance for Bachelor Enlisted Quarters (NAFACINST 11012.114H) October 1975
- E. Construction Criteria Manual (DOD 4270.1-M) October 1972
- F. Design Manual-Mechanical Engineering (NAFAC DM-3) September 1972 with Changes 1,2,3 and 4
- G. A-E Guide (PACNAVAFACENGCOM P-74) May 1975
- H. A-E Guide (SOUTHNAVAFACENGCOM P-141) April 1975 with Change 1
- I. Various Definitive Drawings and Project Drawings
- J. Technical Guidelines for Energy Conservation in New Buildings (NAFAC) January 1975
- K. Technical Guidelines for Energy Conservation in Existing Buildings (NAFAC) January 1975
- L. Design Manual - Troop Housing (NAFAC DM-36) February 1968 with Change 1
- M. Design Manual - Architecture (NAFAC DM-1) October 1974

NOTES ON DESIGN PUBLICATIONS

A. Guide Specification Section 07232 - Ceiling, Wall and Crawl  
Space Insulation

1. Paragraph 6.1 calls for vapor barrier to be installed on the "interior (warm in winter) side of the construction".

A. Guide Specification Section 07241 - Roof Insulation

2. Paragraph 6 calls for vapor barriers as follows:
  - 6.4 Poured Concrete Decks-Ventilating Felt
  - 6.5 Precast Concrete Decks-Asphalt base sheet
  - 6.6 Structural Cement-Fiber Decks-Asphalt base sheet
  - 6.7 Wood Decks - Rosin-sized paper or unsaturated felt plus asphalt base sheet
  - 6.8 Gypsum Decks - Ventilating Felt
  - 6.9 Steel Decks - None shown

3. Technical Note G calls for vapor barrier except for metal decks.

A. Guide Specification Section 15 - Insulation of Mechanical  
Systems

4. Paragraph 5.2.1 does not require a vapor barrier jacket for unicellular insulation.

D. NAFACINST 11012.114H - Design Guidance for Bachelor Enlisted  
Quarters

1. Paragraph II-I limits floor to floor height to 10'6" in air conditioned buildings.
2. Most definitive drawings referenced in Paragraph I-B provide floor to floor heights lower than 10'6".
3. Paragraph V-A prohibits air to air heat pumps.
4. Paragraph V-B calls for inside "design" conditions between 75 and 78F and relative humidity of 50% or the outside design dewpoint, whichever is less.
5. Paragraph V-C1(d) calls for bathroom exhaust air to be replaced by infiltration and not included in load calculations.
6. Paragraph V-C generally requires that the cooling load calculations be done as tightly as possible.

7. Paragraph V-H1 calls for the largest possible temperature difference on chilled water systems.
8. Paragraph V-H2 suggests consideration of a separate ducted ventilation system in conjunction with fan coil units.

E. DOD 4270.1-M - Construction Criteria Manual

1. Paragraphs 3-4.1C and 3-4.2B require bachelor officer and enlisted housing floor to floor heights to be the "practicable minimums" considering structural and mechanical systems.
2. Paragraph 8-5.1B calls for inside "design" conditions between 75 and 78F and relative humidity of 50% or the outside design dewpoint, whichever is less.
3. Paragraph 8-5.1E calls for insulation and ventilation of spaces above ceilings in conjunction with air conditioning of existing buildings.
4. Paragraph 8-5.1K calls for ceiling mounted application when using room fan coil units in areas with winter design temperatures of 15F or higher.
5. Paragraph 8-5.3 calls for "A single central plant, or a single refrigeration unit" for buildings.
6. Paragraph 8-5.3B lists various types of buildings and limits of cooling load under which exceptions to the central plant or single unit requirement may be taken.
7. Paragraph 8-5.7A permits the use of a secondary or auxiliary refrigeration system when the "winter" air conditioning load is small.
8. Paragraph 8-5.9 calls for a single chiller (in priorities 6,7 and 8) for loads between 130 and 800 tons, and one, two or three chillers for loads over 800 tons (based on an economic study). Where only personnel comfort is involved the load shall not be "split".
9. Paragraph 8-5.10 suggests that air conditioning equipment be located outdoors to the greatest extent possible, except when in proximity to the ocean.

10. Paragraph 8-5.15B prohibits summer humidity control in priorities 6, 7 and 8 except when the sensible heat factor is less than 0.65. Dehumidification control is permitted in tropical locations when the winter design temperature is higher than 65F.
11. Paragraph 8-7.6 discusses condensation control for cold climates.

F. Design Manual - Mechanical Engineering - DM-3

Chapter 4 Section 4 Part 1

1. Paragraph 1a requires a minimum of 6 air changes per hour.
2. Paragraph 2 requires a maximum of 0.125 CFM/SF or exhaust + 10% or 10 CFM per person in quarters (with smoking).

Chapter 4 Section 4 Part 2

3. Paragraph 1 has no requirement for exhaust air for toilet areas in BEQ's and BOQ's.
4. Paragraph 2 requires toilet areas to be maintained under a negative pressure.

Chapter 5 Section 2 Part 3

5. Paragraph 2 covers the determination of the time of maximum load.

Chapter 5 Section 2 Part 5

6. Table 5-5 calls for long period occupancy spaces to be maintained at 40 to 50% RH.

Chapter 5 Section 2 Part 7

7. Paragraph 2 calls for a minimum of one air change per hour for the purpose of calculating loads.

Chapter 5 Section 2 Part 9

8. Paragraph 6 requires calculation of moisture permeance for very low room dewpoints.

Chapter 5 Section 2 Part 13

9. Paragraph 2a requires computation of the supply air quantity based on room sensible heat gain.
10. Paragraph 2b(1) requires a minimum of six air changes per hour (with bypass if necessary).

11. Paragraph 2b(3) calls for reheat for spaces with low sensible heat factors in order to maintain 6 air changes per hour.

Chapter 5 Section 3 Part 2

12. Paragraph 1a restricts return air from living quarters.

Chapter 5 Section 4 Part 2

13. Paragraph 2c discusses the requirements for control of fan coil units.
14. Paragraph 2d calls for condensate drain piping for fan coil units with certain exceptions.

Chapter 5 Section 5 Part 5

15. This part discusses the various means for controlling refrigeration equipment under part load operation.

Chapter 5 Section 5 Part 9

16. Paragraph 1b(2) suggests 85F condenser water temperature.
17. Paragraph 3f calls for capacity control on cooling towers to maintain 75F water temperature.

Chapter 5 Section 7 Part 1

18. This part discusses the performance characteristics of air cooling equipment at full load conditions.

Chapter 5 Section 7 Part 6

19. Paragraph 2 discusses condensate removal.

Chapter 5 Section 16 Part 1

20. Paragraph 1b calls for insulation with vapor barriers.

Chapter 5 Section 16 Part 2

21. Paragraph 2c(1) does not require drain piping to be insulated.
22. Paragraph 3c does not specifically call for cooling condensate drain pans and piping to be insulated.

Chapter 5 Section 17 Part 4

23. Paragraph 1c limits face and bypass control unless outside air is dehumidified.
24. Paragraph 2c suggests a coil leaving air thermostat when constant cooling and dehumidification are required.

Chapter 5 Section 18

25. Paragraph 4 calls for overtemperature alarms only for electronic equipment facilities.

Chapter 5 Section 19 Part 1

26. Paragraph 2d calls for water drips to be piped to a floor drain.

Chapter 5 Section 19 Part 4

27. Paragraph 1 lists a number of items for architectural coordination.

G. A-E Guide - Pacific Division

1. Paragraph 6.8.2e requires a statement of the control system needed to meet inside temperature and humidity requirements.

Appendix H - Attachment A

2. Paragraph 8 calls for the use of economy cycle.

Appendix H - Attachment B

3. Paragraph 3 calls for foil backed insulation or gypsum board.

Appendix H - Attachment C

4. This attachment sets forth guidance for preparing computer energy analyses.

H. A-E Guide - Southern Division

1. Appendix X Paragraph D(4)(C) calls for a Statement of any special dehumidification requirements.

J. Technical Guidelines For Energy Conservation In New Buildings

1. Paragraph 3.2.2.4(2) suggests the use of a runaround system within an air handling unit in order to achieve some reheat without the use of new energy.

2. Paragraph 3.2.4 suggests various types of refrigeration heat recovery which may be used for heating or reheat.
3. Paragraph 3.3.20 calls for a minimum 20F rise in chilled water systems.

L. Design Manual - Troop Housing - DM-36

Chapter 1 Section 6

1. Paragraph 2c calls for fan and coil units for air conditioning, while paragraph 2a(4) calls for room type fan coil units for individual rooms. (Enlisted)

Chapter 3 Section 3

2. Paragraph 1c calls for fan coil units and no air conditioning for toilets, corridors, stairways or storage rooms. (Officer)

M. Design Manual - Architecture - DM-1

Chapter 1 Section 4

1. Paragraph 2 suggests that climate be carefully considered before starting design.

Chapter 2 Section 2

2. Paragraph 4d discusses climate related design criteria for tropical humid zones.
3. Table 2-1 (Roofs) requires that insulation not be used over concrete slabs, that the underside of the slab be coated with an organic vapor barrier, flat roofs be avoided, cellular glass insulation is satisfactory, vegetable fiber board is unsatisfactory, insulation should be applied beneath roof slab, and that vapor barriers be used under insulation when it is above the roof slab.
4. Table 2-2 (Walls) requires that coatings be used to reduce moisture penetration and deter algae growth, shadow grooves not be used and that jalousies not be used for air conditioned spaces.
5. Table 2-3 (Wall Materials and Finishes) requires that where moisture is not a problem, gypsum and cement plasters are satisfactory, portland cement plaster and cement plaster on lath not

be used in humid areas, organic fiber wall-boards not be used when subject to wetting and drying, exposed masonry is satisfactory when not subject to moisture, ferrous metal door bucks not be used, organic fibrous insulations are subject to moisture damage and should not be used and that cellular glass should be used rather than fibrous glass, mineral wool and organic fiber insulation materials,

Chapter 2 Section 4 Part 5

6. Paragraph 6b discusses the effects of condensation.

Chapter 3 Section 2 Part 3

7. Paragraph 2b covers the application and selection of insulating materials.
8. Table 3-4 shows the moisture resistance of insulating materials.

Chapter 3 Section 2 Part 5

9. Table 3-6 lists the moisture resistance properties of partition facings.

### Comments

A-1. The Guide Specification for ceiling, wall and crawl space insulation was obviously written for cold climates since vapor barriers are recommended on the interior side of construction. Where vapor barriers are used in humid climates they should be on the exterior side of the construction since that is where the vapor pressure is higher.

A-2. This paragraph calls for various types of vapor barriers in roof construction. Since the roof membrane itself is a vapor barrier and since in most all cases any additional vapor barrier would be on the room side of the insulation, a problem is created in humid climates whereby the two vapor barriers create a situation which makes it virtually impossible for any moisture in the roof insulation to escape. In climates that are variable from summer to winter, there are changes in direction of vapor flow thus allowing any accumulation of moisture to escape during seasonal changes in weather. In humid climates where the flow of vapor is unidirectional continuously the opportunity does not exist for any change in direction of vapor flow so that it is essential to permit the moisture which does enter the roof insulation to escape. In this case the escape would occur into the space. Since the roof membrane itself acts as a good vapor barrier, the magnitude of this vapor entering the space is relatively small and should not create a problem or a cooling load that is of any significance.

A-3. This technical note in the Guide Specification calls for

vapor barriers except with metal decks. This exception should be expanded to exclude vapor barriers for all types of roof construction for the reasons shown in A-2.

A-4. The Guide Specification for insulation of mechanical systems does not require a vapor barrier jacket for unicellular insulation since it would appear that the insulation itself might be relatively impermeable. This does not really hold true, especially in cases where the vapor flow is constant and continuous as would be found in cold piping in humid climates that operates all year round. Even though unicellular insulation does have some resistance to vapor flow, the fact that vapor flow is continuous in humid climates causes eventual saturation of this insulation over a period of one or two years. In applications of unicellular insulation where cooling is not required year round, the vapor that does migrate into the insulation is able to escape during periods when the cooling is not operating. This holds especially true where piping is not in the conditioned space such that the ambient vapor pressures are significantly higher than the vapor pressures at the surface of the cold pipe.

D-1. Floor to floor height limitations in air conditioned buildings can preclude consideration of ducted systems. Such limitations frequently limit the types of mechanical systems that can be considered by the designer. In the case of humid climates these limitations have led to the selection of fan coil units which are about the only type of system that can be

utilized with floor to floor height limitations that are shown.

D-2. Where definitive drawings are used the floor to floor heights are frequently lower than 10'6" in order to achieve economy. This limits the designer in selection of mechanical systems. In humid climates where ducted systems may be desirable for the purpose of controlling humidity either the definitive drawings should show an option for higher floor to floor heights or a separate set of definitive drawings for use in humid climates should be prepared.

D-3 prohibits air to air heat pumps. While heat pumps would rarely be considered in humid climates since there is little or no need for heating, the advantage that they offer is a low evaporator temperature which provides dehumidification. In those humid climates where heating is required air to air heat pumps should be permitted, including through the wall or window type heat pumps. When heat pumps are operated on cooling they perform almost identically to through the wall or window type air conditioning units which have been proven to keep the humidity under control and therefore minimize moisture problems in humid climates.

D-4. While the Design Guidance calls for design conditions between 75 and 78F and relative humidity of 50%, there are no requirements for the continued maintenance of these conditions. Designers utilize these criteria in the selection of the capacity of air conditioning systems but rarely give consideration to the ability of the type of air conditioning

system selected to continuously maintain these conditions throughout the year. In humid climates where control of indoor humidity is essential in reducing or eliminating moisture problems it is necessary to require that the air conditioning system not only have the ability to maintain humidity control at "design" conditions, but under any conditions that will be experienced throughout the year.

D-5. The use of infiltration as makeup for bathroom exhaust air in humid climates is not a good idea because outdoor moisture becomes introduced directly into the space without any continuous and positive means of controlling moisture. Where dehumidification is necessary it is usually more efficient to dehumidify outside air prior to introduction into the space rather than to supply cold air which will absorb moisture in the infiltration air. Treating makeup air in the supply system will also tend to pressurize the spaces and therefore reduce the infiltration of unwanted moisture.

D-6. While it is desirable that cooling load calculations be as accurate as possible in order to avoid oversizing of air conditioning equipment, it is even more essential to consider the part load performance in terms of humidity control in humid climates. Again, consideration must be given to the fact that under light sensible load conditions the latent loads are frequently still substantial and not in proportion to the sensible loads. At design conditions most air conditioning equipment is barely able to remove the latent load in humid climates, and under part

sensible conditions little consideration is usually given to the fact that certain types of air conditioning systems are unable to remove the latent loads that exist.

D-7. While it is desirable to have a chilled water temperature difference as large as possible in order to reduce pumping energy, the use of large temperature differences in chilled water coils in humid climates can reduce the latent ability of those coils, especially under light load conditions. This problem is especially acute when one and two row coils are utilized. Figure 5-1 shows the relationship between total cooling capacity and sensible cooling capacity as a function of water temperature rise for a three row coil in a fan coil unit operating at 45F entering chilled water temperature. It can be seen that the latent capacity drops off as the water temperature rise increases, thus reducing the latent capacity at full load, and depending upon the type of system and method of control, possibly providing little or no latent cooling ability at light sensible loads.

D-8. While it is suggested that consideration be given to a ducted ventilation system in conjunction with fan coil units, this contradicts D-5 which calls for makeup air to be replaced by infiltration. In any event, in most cases where fan coil units are utilized, separate ducted ventilation systems are not employed. The reasons are not known, except that economy may be one of them. A fairly common practice in commercial buildings in humid climates is

to utilize a separate ducted ventilation system in conjunction with fan coil units in order to provide a constant supply of dehumidified air. Buildings employing such systems seem to have better success in controlling moisture problems. The reasons for this are quite obvious in that the humidity of the ventilation air can be continuously controlled. However, when used in conjunction with individual room fan coil units the smallest units available are generally much too large for the loads that are experienced since the ventilation air provides some sensible cooling in addition to the latent cooling of the ventilation air. When fan coil units are used in small rooms such as bedrooms in humid climates the net room cooling load after consideration of the cooling done by the ventilation system becomes very small and typically much smaller than the ability of the smallest fan coil units. Therefore, this suggestion is probably not appropriate in humid climates since the fan coil units will be substantially oversized and their part load performance would yield less than comfort conditions.

E-1. The way in which these floor to floor height considerations have been interpreted appear to be primarily with respect to structural considerations rather than both structural and mechanical. This holds especially true in the preparation of definitive drawings where the design of the mechanical system is usually omitted and left for site adaptation due to the varying climates in which these definitive drawings will be utilized. Also see the comments on D-1 and D-2.

E-2. See comments on D-4.

E-3. When air conditioning existing buildings in humid climates special consideration should be given to the ventilation of spaces above ceilings. In multistory buildings ventilation of spaces above ceilings can cause condensation on the underside of floor slabs when the dew point of the ventilation air is above the dew point temperature of the floor slab. Since most ceilings are highly permeable, it is questionable whether ventilation with outside air above the ceiling should be utilized since the latent cooling load of the space will be increased. While vapor barriers would reduce this latent heat gain it is usually impractical to install vapor barriers in the ceilings of existing buildings, especially when considering the difficulty of adequately sealing the vapor barrier.

E-4. While the use of ceiling mounted fan coil units is recommended whenever the winter design temperature is 15F or higher this has not been a universal practice. Where separate ventilation systems are not utilized the fan coil units are usually placed underneath the window and outside air is introduced through the fan coil unit. In either case in humid climates the use of fan coil units where cooling is required year round creates the potential for moisture related problems, especially drain pan overflows. Where dehumidification is continuously necessary the cooling coil always operates wet and there is condensate continuously flowing into the drain pans and out of the building. With this moisture continuously present it

attracts lint and foreign materials from the air being handled and also provides a place in which mold growths can flourish, thus giving the tendency to clog the drain outlet. Unless frequent periodic maintenance and cleaning of drain pans is accomplished, there will be overflows. Whether the fan coil unit is located under the window or in the ceiling, the damage associated with drain pan overflows can be substantial and can remain undetected for periods of time permitting the water to travel great distances throughout the building and do damage in other spaces, both visible and invisible. Especially in ceiling mounted applications access to periodically inspect and clean drain pans is quite difficult and usually is not accomplished until an overflow occurs. Also, it is occasionally found that in setting fan coil units the units themselves are not properly levelled so that the condensate flow in the drain pan almost fills the pan before it starts to go out of the drain itself. Where fan coil units are utilized each one should be tested prior to acceptance in order to demonstrate that water collected in the drain pan will flow out and not accumulate.

E-5. The use of a single refrigeration unit or a single central plant for buildings in humid climates contributes to moisture problems in buildings as well as to increased operating cost. In order to preclude moisture problems it is essential that a reliable and constant supply of chilled water be available. With the majority of the hours in a year at very light loads, the use of a single refrigeration unit can cause fluctuations

in chilled water temperature. The amplitude of those fluctuations will depend upon the manner in which the chiller itself is controlled. However, since there are so many hours when the load is less than 10 or 20% of the capacity of the unit when dehumidification is still essential, most chillers will cycle off, thus allowing the chilled water temperatures to fluctuate unless hot gas bypass is used. Chiller reliability is another major concern in that with a single chiller it must operate continuously and reliably all year long in humid climates. As a practical matter this is too much to expect from any piece of equipment as complex as a chiller. Whenever the chiller does not function properly and/or chilled water temperatures are not maintained at their design conditions, the ability of the air handling systems to control humidity is substantially impacted. Since there are so many hours in humid climates at light load conditions, the efficiency of chillers under these conditions becomes very poor. Were multiple chillers to be utilized they would be able to operate more efficiently and probably preclude the need for hot gas bypass. The use of multiple chillers would increase the plant reliability as well.

E-6. No exceptions are listed for buildings in humid climates.

E-7. While this paragraph pertains primarily to buildings that experience both heating and cooling loads, this type of consideration ought to be given to buildings in humid climates that experience wide variations in cooling loads, especially with many hours at light loads.

E-8. See the discussion under E-6 above.

E-9. The reliability of outdoor air conditioning equipment is not nearly as good as indoor equipment. Especially when only a single air conditioning unit is utilized, it has more of a tendency to break down and therefore create problems in the conditioned space. In humid climates the tendency for condensation in and on the air conditioning unit and the humid air aggravate the corrosion of the equipment and especially of the controls, thus contributing to loss of reliability.

E-10. The prohibition on summer humidity control in Priorities 6, 7 and 8 except when the sensible heat factor is less than 0.65 will not permit the elimination of moisture problems in humid climates. Under design conditions the sensible heat factor is rarely less than 0.65. However, during almost all hours of operation throughout the year in humid climates the sensible heat factor will be less than 0.65. Thus, unless humidity control is utilized, the humidity will not be controlled and moisture problems will result. One way of solving this problem would be to expand the consideration of sensible heat factor to all hours of the year. While dehumidification control is permitted in tropical locations, it does not say what types of dehumidification nor is it suggested that it may be essential under certain conditions in certain buildings in tropical locations.

E-11. While this paragraph discusses condensation control for cold climates there is no discussion of condensation control

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for humid climates.

F-1. In constant volume systems (such as fan coil units) the use of six air changes per hour as the minimum circulation rate can lead to oversizing of air handling equipment for those situations in which the sensible load is low and the latent load is high. Then when operating at light load conditions the air handling systems frequently do not have the ability to do dehumidification. The more oversized the units are to meet this air change rate the worse the part load performance becomes with respect to dehumidification.

F-2. This paragraph permits ventilation air to be provided by infiltration. As indicated previously in D-5 this is not desirable. The use of only 10% excess ventilation air over and above exhaust requirements is questioned for windy locations in humid climates. Since wind pressure will substantially influence infiltration and the quantity of outside air through louvers, the use of only 10% excess is not sufficient to overcome this effect. While there are no studies or experiments that have measured or evaluated these conditions, it would be our opinion that 10% is not sufficient, and that 20 to 30% in windy locations would be more appropriate. This becomes especially critical during rain storms when the wind velocities are high and the ambient dew point temperature is equal to or close to the ambient dry bulb temperature, thus creating very delicate conditions for condensation. It is suggested that ASHRAE Standard 62-73 be utilized to establish ventilation requirements.

F-3. No requirements are specified for toilet exhaust in

BEQ's and BOQ's. Since these facilities are sufficiently standardized toilet exhaust requirements should be established.

F-4. This paragraph requires toilet areas to be maintained under a negative pressure. Negative pressures in toilet areas will cause infiltration of outdoor air in humid climates. This requirement should be changed to suggest pressures in toilet areas that are positive with respect to outside and negative with respect to the rooms that are adjacent. Even though local practice and/or Building Codes may permit natural ventilation of toilet rooms in tropical climates, it should not be permitted in air conditioned buildings. Natural ventilation provides a means for humid air to migrate not only into the toilet and shower areas, but also into the conditioned spaces.

F-5. This paragraph covers the determination of time of maximum load only. An evaluation should also be made of the minimum load conditions in humid climates in order to establish the ability of the air conditioning system to maintain comfort conditions under minimum load conditions.

F-6. Table 5-5 calls for long period occupancy spaces to be maintained at 40 to 50% relative humidity. Achieving these conditions becomes especially difficult in humid climates. The ASHRAE Comfort Standard allows the relative humidity to go as high as 60% providing the temperature is kept below 78F. Since it is much more reasonable to achieve conditions within the ASHRAE Comfort Chart it is suggested that these criteria be expanded, providing that the air conditioning

system is able to maintain these conditions in humid climates.

F-7. Using a minimum of one air change per hour for the purpose of calculating cooling loads may contribute to oversizing of cooling equipment in some buildings in humid climates, thereby making dehumidification more difficult to achieve. In locations where wind velocities are low and where buildings are relatively tight, the infiltration can be expected to be less than one air change per hour and still be in excess of the exhaust air requirements.

F-8. This paragraph requires calculation of moisture permeance only for spaces with very low room dew point temperatures. It should also be required for those conditions where there is a large dew point temperature differential between inside and outside. It is suggested that whenever the design ambient dew point exceeds the design room dew point by more than 20F, permeance calculations shall be made. Even though the latent load thus calculated may be small, it will call the designer's attention to the possible need for vapor barriers.

F-9. This paragraph requires computation of the supply air quantity based on room sensible heat gain only. In those situations where the latent heat gain is substantial it may be necessary to establish supply air quantities based on latent pick up ability, rather than sensible. This situation is quite common in spaces having high density occupancy even in mild climates. In humid climates it becomes even more pronounced when consideration is given to the latent load from the

occupants, from infiltration and from permeance through the structure. Basing the supply air quantity on sensible heat gain alone will result in high humidity conditions, especially at light loads. Where space temperature is controlled by thermostats (which is just about everywhere) the only way to insure that the humidity remains within the comfort zone is to do so psychrometrically by means of a properly controlled air conditioning system which will yield humidity control over the entire range of sensible loads encountered by the system.

F-10. As indicated in F-1 above, the use of six air changes per hour without specific humidity control can result in oversizing of air handling equipment and loss of comfort conditions. Even if a bypass type system is utilized in order to achieve six air changes per hour there is no guarantee that humidity control will be achieved.

F-11. Even though this paragraph calls for reheat for spaces with low sensible heat factors in order to maintain six air changes per hour (and to control humidity) its actual use has obviously been curtailed. There is no other means within conventional air conditioning systems to achieve humidity control except with reheat. Unfortunately many of the reheat systems that have been utilized have been wasteful. It is possible to have properly designed and controlled reheat systems that minimize the use of reheat energy and/or utilize condenser heat or recovered heat for the purposes of reheat. Where humidity control is essential as in humid climates, the

use of reheat is virtually mandatory, especially in buildings with highly variable sensible cooling loads and long hours at light sensible cooling loads.

F-12. This paragraph restricts the use of return air from living quarters for hygienic reasons. So long as adequate ventilation air is provided to dilute odors, we can find no justification for this restriction. Experience with central air conditioning systems in living quarters has shown that those systems serving multiple quarters have not yielded complaints, providing that they are able to control comfort.

F-13. The discussion on means of control for fan coil units is quite adequate with respect to control of temperature. However, it does not say anything with regard to the control of humidity. Experience has shown that a combination of fan and water control yields better humidity control in humid climates. However, regardless of whether the fan coil units are controlled by water alone, by fan alone, or by a combination of fan and water, they are unable to provide humidity control within the comfort range, especially at light sensible load conditions. Where light sensible load conditions exist for a significant number of hours in a year the fan coil system concept controlled in any known fashion will not provide comfort conditions.

F-14. Where fan coil units are utilized for cooling on a year round basis, adequate provisions should be made for regular routine cleaning of the drain pans and drain lines.

The drain lines should not be less than three-quarter inch. Consideration should be given to provisions that would allow for drain pan overflows without damaging property. Where fan coil systems operate on cooling continuously this may preclude the use of ceiling mounted fan coil units and may require the installation of a floor drain below the fan coil unit when mounted under the window. While these suggestions may seem rather severe, there is sufficient field experience to indicate that fan coil unit drains become clogged and overflow on a regular basis when they are operated on cooling for most hours of the year. Making adequate provisions to handle drain pan overflows would to a great extent eliminate the economy of the fan coil system in comparison with other system types. When combined with the consideration that fan coil units are unable to maintain humidity control it is believed that there is sufficient justification for prohibiting the use of fan coil units in air conditioned buildings in humid climates operating year round.

F-15. This part discusses the control of capacity reduction in various types of chillers. With the exception of hot gas bypass on centrifugal chillers there is no discussion on the means for controlling the operation at very light loads for long periods of time in order to maintain design chilled water temperatures. There is also no discussion on the means for controlling multiple refrigeration machines operating at part load. Especially when there are long hours at light loads short cycling results when attempting to maintain

chilled water temperatures. This short cycling impacts on the reliability and maintenance required, thus contributing to breakdowns.

F-16. This paragraph suggests 85F condenser water temperatures. In humid climates where the design wet bulb temperatures are in the 80's this suggestion is unrealistic. It would be more economical to select cooling towers for 90 or 95F leaving water temperature. While this may require somewhat higher compressor energy, it may end up saving on cooling tower fan energy since the cooling tower fans can cycle more often rather than running all the time or most of the time. Also, the larger cooling tower could operate under natural draft conditions during periods of light load and thus not use any fan energy. It should be noted that there are substantial differences in both fan energy and natural draft performance between blow through type cooling towers and draw through type cooling towers. The draw through type cooling towers not only have substantially greater natural draft capacity, but they also require on the order of one-third the horsepower that blow through type cooling towers require. On a life cycle cost basis draw through type cooling towers would probably yield much lower costs than blow through type towers in humid climates having long hours of cooling operation.

F-17. This paragraph calls for capacity control on cooling towers to maintain a 75F condenser water temperature. So long as the cooling tower has the ability to make water at temperatures lower than 75F and so long as the chiller can

operate at these lower condenser water temperatures, it should be permitted. A tradeoff analysis should be made to determine if the saving in refrigeration energy more than offsets the expenditure in cooling tower fan energy in order to obtain lower condenser water temperatures.

F-18. This part discusses the performance characteristics of air handling equipment, but only at full load conditions. It suggests a maximum cooling coil face velocity of 550 feet per minute but does not indicate the merit of evaluating lower face velocities from the standpoint of life cycle cost. An excellent treatise on this subject appears in the article "Air Handling Unit Design For Energy Conservation" in the June 1977 ASHRAE Journal in which it is indicated that face velocities on the order of half of those used in the past may well be optimum from a life cycle cost standpoint. Especially in humid climates, the lower cooling coil face velocities that would probably result from such studies would be able to provide better dehumidification not only at full load, but also at part load. There is no consideration given to the performance of air handling equipment at light load conditions in humid climates, especially with respect to dehumidification. Such an analysis should be made in order to demonstrate the ability of the system to provide adequate dehumidification under light load conditions.

F-19. This paragraph discusses condensate removal. There is no requirement for consideration of drain pan overflow. Esp-

ecially when air handling equipment is located within a building and above occupied spaces, it is well worth considering the need for supplementary drains in the event of a drain pan overflow. In humid climates where there is almost continuous condensate flow from cooling coils the opportunity for clogging the drain line increases substantially.

F-20. This paragraph calls for vapor barriers to be utilized but only requires that "suitable" ones be used. For piping in duct work systems that do not carry cold fluids 12 months of the year most any decent vapor barrier is suitable. However, when cold fluids are utilized 12 months of the year any moisture that does get into the insulation never has an opportunity to escape. This situation will exist with virtually any kind of vapor barrier, so that saturation of the insulation is inevitable, the only variable being the number of years that it takes to reach saturation. At some point in this process the surface temperature of the vapor barrier is reduced below the ambient dew point temperature thus causing additional condensation on the surface of the insulation which may drip. The ultimate solution to this problem in humid climates with continuous cold fluid circulation is to allow for the eventual replacement of insulation, thus necessitating accessibility for replacement. Also, with this in mind cold fluids should not be run through occupied spaces where condensation can occur or where replacement of insulation is impractical. The thrust of this argument is to keep continuously cold fluid handling systems away from the occupied spaces under such conditions.

F-21. This paragraph does not require the insulation of drain piping. Where substantial latent load exists and where the condensate flowing through the drain piping is at or near the saturation temperature of the air leaving the coil, the surface temperature of the condensate drain line will approach that saturation temperature and can be below the room dew point temperature thus causing condensation. Therefore there will be situations, especially in humid climates where there are substantial latent loads which can cause condensation on the exterior of uninsulated drain lines.

F-22. This paragraph does not specifically call for cooling condensate drain pans and piping to be insulated, yet the discussion under F-21 indicates that there are conditions under which insulation should be utilized.

F-23. This paragraph limits face and bypass control to only those conditions where outside air is dehumidified, yet F-10 suggests the use of face and bypass control in order to achieve six air changes per hour. In humid climates and where high internal latent loads exist the dehumidification of outside air in conjunction with face and bypass control systems must not only dehumidify the outside air, but must also have the ability to absorb the internal latent load as well, thus making such a system possible but impractical for use in humid climates.

F-24. This paragraph suggests control of coil leaving air temperature when constant cooling and dehumidification are

required. This concept will work to achieve humidity control only when used in conjunction with some form of reheat or with a variable air volume system. It would also be desirable where humidity control is essential to employ both a humidistat and/or a thermostat to control supply air temperature arranged so that both the temperature and humidity are satisfied. This concept is utilized in various forms of reheat type systems in which the humidistat can overcall the thermostat and lower the cooling coil discharge temperature in order to control humidity.

F-25. This paragraph calls for overtemperature alarms only for electronic equipment facilities. In buildings in humid climates where humidity control is essential in order to prevent moisture problems, some type of alarm system would be highly desirable in order to alert operating and maintenance personnel as to the existence of a problem. The chilled water system should be alarmed to indicate when the temperature rises above a preset value such as that at which dehumidification is no longer achieved. This value would probably be about 48F for chilled water systems. In addition, an alarm sensing humidity in some typical space should be employed set at something like 70% RH.

F-26. This paragraph calls for water drips to be piped to floor drains. Especially in equipment rooms that are unconditioned, condensation drips from the various components in air conditioning equipment and is difficult to collect and pipe to a floor drain. This problem may be minimized by

the design of equipment pads and floor slope.

F-27. While this paragraph mentions a number of items for architectural coordination, no consideration is given to moisture problems associated with air conditioned buildings in humid climates. Items that should be stressed here include the permeance of the various building materials, the location and design of equipment spaces and the routing of mechanical services through the building relating to condensation and accessibility.

G-1. This paragraph requires a statement of the control system needed to meet inside temperature and humidity requirements. A further statement should be required that would demonstrate the ability of the control system to control humidity under light part load conditions. This should cause the designer and reviewer to evaluate the capability of the air conditioning system and the control system to maintain humidity control.

G-2. This paragraph calls for the use of economy cycle. In humid climates where there few if any heating degree days the economy cycle will never be utilized. Having the large outside air dampers associated with economy cycle can only create more damper leakage and thus higher sensible and latent cooling loads. The use of economy cycle should not be required in humid climates.

G-3. While foil backed insulation or gypsum board provides a good vapor barrier in itself, it is almost totally dependent upon good quality sealing of the joints in order to achieve

vapor barrier performance. Since the use of these materials virtually implies that the vapor barrier would be on the inside of the construction, its location is quite improper for use in humid climates. If and when vapor barriers are necessary in humid climates they should be placed on the exterior of the construction, not on the interior.

G-4. This attachment sets forth guidance for the preparation of computer energy analyses. When performing such analyses on air conditioned buildings in humid climates it is essential that the computer program consider the moisture performance of the air conditioning system over the entire range of conditions to be experienced and it is desirable to have the computer program consider the moisture flow through the building elements when it amounts to something.

H-1. This paragraph calls for a statement of any special dehumidification requirements. A statement of any dehumidification requirements should be made along with an evaluation of the manner in which the proposed design will insure that comfort conditions will be maintained.

J-1. This paragraph suggests the use of a run around system as a means of providing some reheat where cooling and/or dehumidification are required for long hours. Where the quantity of reheat required in order to achieve humidity control is substantial, consideration certainly should be given to such a system.

J-2. Same comment as J-1.

J-3. This paragraph calls for a minimum 20F rise in chilled water systems. See the comment on D-7.

L-1. This paragraph virtually dictates the use of fan coil units for air conditioning in troop housing. With all of the problems outlined in this report, we cannot see the justification for this requirement in humid climates.

L-2. See L-1 above. The prohibition on air conditioning at least for toilets and interior corridors in air conditioned buildings in humid climates is not justified in view of the moisture problems that occur. See F-3 and F-4. Whenever non-air conditioned spaces are included in air conditioned buildings in humid climates, special care and attention must be paid to their thermal and moisture flow treatment in order to preclude moisture problems. These unconditioned spaces must be insulated, vaporproofed and ventilated. In many instances it will be less expensive and more practical to air condition these spaces than it will be to treat them properly from the standpoint of moisture control. So long as stairways are "open", outside the building, and allow free air circulation, no problems should occur. Storage rooms may or may not be air conditioned depending upon the nature of the material stored therein. If personal articles and/or stored materials subject to damage by mold or mildew are to be in these rooms they should be air conditioned and/or dehumidified.

M-1. This paragraph suggests that a number of factors in addition to climate be carefully considered before starting

design. Here it should be emphasized that when air conditioning is to be employed in buildings in humid climates special consideration ought to be given in view of the moisture problems associated with these buildings.

M-2. This paragraph discusses climate related design criteria for tropical humid zones. Consideration should be given to possibly subdividing this category into humid island climates and humid inland climates, since there are differences in temperatures, humidities and wind conditions in these two types of humid climates. Reference 30 provides a good discussion of these climates and the kinds of design approaches that are best suited in the absence of air conditioning. These approaches obviously must be tempered and reevaluated when air conditioning is employed. Since most of the discussion on design criteria for tropical humid zones is based upon non-air conditioned buildings, consideration should be given to expanding or separating the material that applies to air conditioned buildings from non-air conditioned buildings.

M-3. This table outlines certain suggestions and requirements for roofs in tropical zones. In air conditioned buildings we can find no reason to preclude the use of insulation over concrete slabs provided that a builtup roof is utilized that will serve as a vapor barrier. When the vapor barrier is on the exterior of the building (as it should be in such a climate) the interior side of the roof should not be coated with a vapor barrier since any moisture that does enter the roof

should be allowed a means for escape. While flat roofs should be avoided in both air conditioned and non-air conditioned buildings, it is not nearly so essential in an air conditioned building with an insulated roof, since the insulation serves to keep the heat out of the conditioned space, whereas in a non-air conditioned building a ventilated attic would tend to do the same thing.

Insulating materials that are not hygroscopic are preferred since in addition to not absorbing moisture they also are not subject to vermin. In modern concrete construction it is typically difficult and impractical to apply insulation beneath the roof slab unless a suspended ceiling is utilized. With air conditioned buildings that approach creates other problems with ventilation and moisture flow. In air conditioned buildings we cannot agree that vapor barriers should be used underneath insulation when it is above the roof slab for the reasons cited above for not coating the under side of the slab with a vapor barrier.

M-4. This table provides various requirements for walls. We concur that exterior coatings should be selected to both reduce moisture penetration by providing a good vapor barrier and to deter algae growth. In the search of the literature we were unable to find any information which correlates the permeability of various finishes with their ability to resist algae growth. Since these two criteria are among the most significant of this entire study, it is suggested that an experimental study be undertaken to evaluate the moisture

permeability and the resistance to algae growth for the various types of finishes utilized on the walls of buildings. Since buildings in humid climates must be painted much more frequently than in any other type of climate, the results of such a study should enable both a reduction in the maintenance cost of buildings in humid climates and provide improved appearance for longer periods of time.

M-5. This table should be separated for air conditioned and non-air conditioned buildings.

M-6. This paragraph discusses the effects of condensation primarily in non-air conditioned buildings in humid climates and in heated buildings. Additional discussion should be included on condensation problems in air conditioned buildings in humid climates.

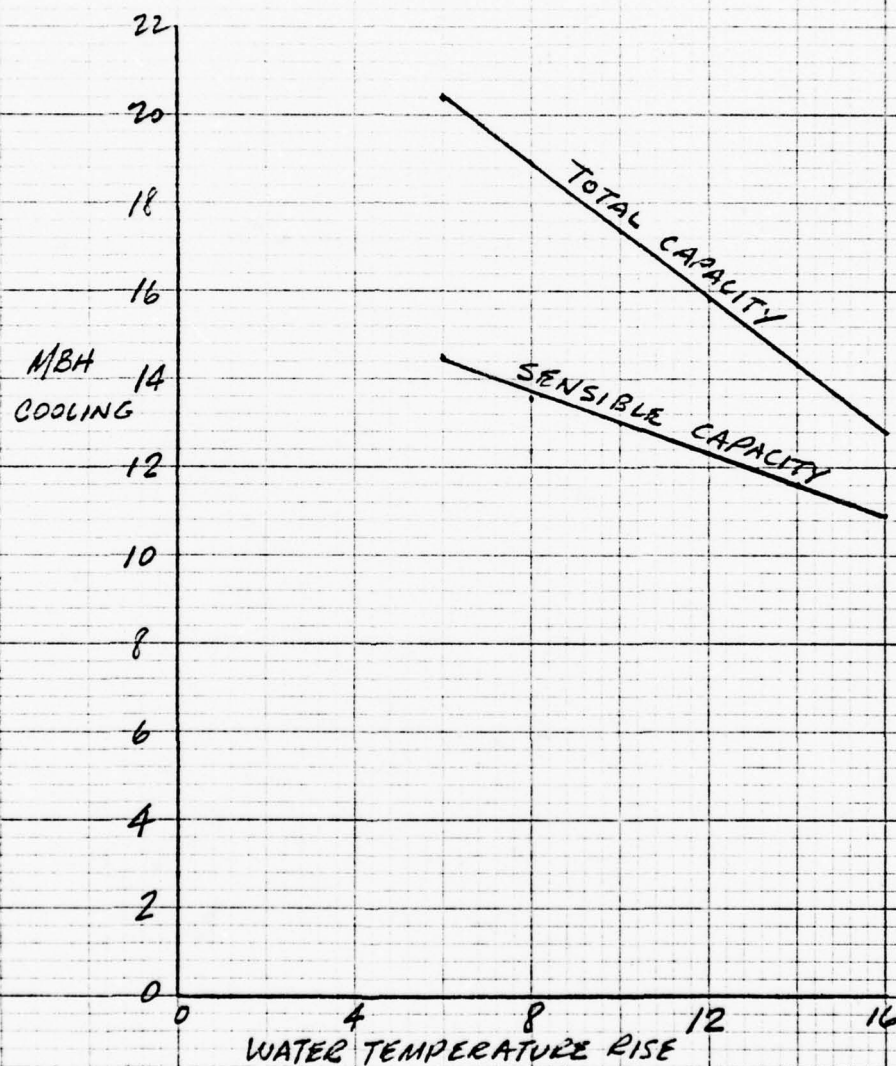
M-7. This paragraph covers the application and selection of insulating materials but is somewhat inconsistent with M-5 above. The discussion of vapor barriers should be expanded to include consideration of air conditioned buildings in humid climates in which the vapor barrier should be indicated on the exterior side of construction when necessary and that the permeance is of much more significance in humid climates with year round air conditioning.

M-8. This table shows the moisture resistance of various insulating materials. It would appear that the moisture resistance capabilities were primarily considered for insulat-

ing materials used in connection with heating requirements in which case the vapor pressure differentials are variable throughout the year and are not of large magnitude. Where the vapor pressure differential across the insulation is high and continuous, the moisture resistance of some of the insulations listed as good and excellent are not quite as good as indicated, nor are all of the materials listed as excellent equally excellent.

M-9. This table lists the moisture resistance properties of partition facings. See M-5.

# FAN COIL UNIT CAPACITY VS TEMPERATURE RISE



CARRIER SERIES 42 FAN COIL WITH 3 ROW COIL SIZE 5  
 45F ENTERING WATER, 67F WET BULB, 80F DRY BULB

## CHAPTER 6

### ANALYSIS AND DISCUSSION

#### Purpose

The purpose of this Chapter is to analyze and discuss the basic principles associated with the design of air conditioned buildings in humid climates. While Chapter 5 discusses the requirements of the various Navy design criteria, this Chapter presents the considerations relating to the successful performance of air conditioned buildings.

#### Climate

While there is no precise definition for a humid climate, we will attempt to set forth several specific criteria that might be considered for use as design criteria.

Based on our observations and reports of moisture problems, it would appear that areas in which the design wet bulb temperature is 80F or higher generally experience moisture problems. Since these climates experience many hours at high wet bulb temperatures, the ability of the air conditioning system to handle latent loads due to ventilation and infiltration becomes more critical. Since there is frequently less variation in wet bulb temperatures than in dry bulb temperatures, we feel that strong consideration should be given to utilizing the 1% design value for wet bulb temperatures, rather than the 5% value currently used. This would not only permit adequate consideration of latent loads

in the space, but also would provide cooling towers that were more efficient and better able to permit the operation of chillers at their rated chilled water temperature during times when it is needed the most.

In evaluating the weather data at locations where problems have been experienced it would appear that there is some consistency between the occurrence of problems and the frequency of wet bulb temperature occurrences above a given value. The weather data in NAFAC P-89 shows the number of hours during the warmest six month period in which the wet bulb temperature exceeds 67F wet bulb and 73F wet bulb. The most severe problems occur in locations where 73F wet bulb is exceeded for more than 2,000 hours per year, while consideration of all problem areas generally include those locations with more than 1,750 hours per year above 73F wet bulb. Referring to the 67F wet bulb data the most severe locations exceeded 67F wet bulb for 4,000 hours per year, while the majority of the problems encompassed those areas having more than 3,500 hours per year above 67F wet bulb.

Therefore, in order to determine the locations for which criteria for air conditioning buildings in humid climates should be utilized, we suggest the values shown in Table 6-1. The humid climate design criteria should be required for climates having either 3,500 hours per year above 67F wet bulb or 1,750 hours per year above 73F wet bulb.

TABLE 6-1  
HUMID CLIMATE DESIGN REQUIRED  
FOR AIR CONDITIONED BUILDINGS

<u>WET BULB</u> <u>TEMPERATURE</u>	<u>HOURS ABOVE</u> <u>WB TEMPERATURE</u>
67	3,500
73	1,750

Thermal Performance

Insulation is required in order to achieve exterior surface temperatures that are above the ambient dew point temperature in air conditioned buildings in humid climates. Where the indoor dry bulb temperature is below the ambient dew point temperature, the exterior surface of a poorly insulated wall or roof can be below the ambient dew point temperature and cause condensation and mold growth. This is especially prevalent in areas having little air flow and little sunshine. Where air flow and sunshine exist the vapor that is condensed on the exterior surface will evaporate more quickly due to the air motion and/or the solar heat.

The need for insulation becomes even more critical when considering the variability of wind velocity in humid climates and its effect on the surface conductance and surface temperature.

Figure 6-1 shows the relationship between wall surface temperature and ambient temperature for still air and a wind velocity of  $7\frac{1}{2}$  miles per hour for walls having thermal

resistances of 1.11 and 10.0. It can be seen that in the wall having a thermal resistance of 1.11, with still air at 80F ambient temperature, the surface temperature is 77F dry bulb. Since there are many hours at 80F ambient dry bulb with dew point temperatures above 77F, condensation will ensue. Taking the same conditions with a wall having a thermal resistance of 10, it can be seen that the surface temperature with still air is slightly over 79F. While there still may be some condensation during those hours in which the ambient dew point is in excess of this temperature, the number of hours per year is substantially lower than those in which the ambient dew point is above 77F. Figure 6-2 shows a plot of the temperatures through a wall having a thermal resistance of 1.11 at both 7½ mile per hour wind velocity and still air and for ambient temperatures of 80F and 100F. The difference between the outside surface temperatures for still air conditions and for 7½ mile per hour wind velocities should be noted. It should also be recognized that the surface conductances as a function of wind velocity will also vary among the various types of materials utilized, with the rougher materials having higher conductances and the smoother materials having lower conductances.

Condensation can also occur on indoor surfaces when the space humidity is high and variable, such as would occur at light load conditions with some types of air conditioning systems. The inside surface temperature of walls and ceilings is generally very close to the room dry bulb temperature. If the

space dew point temperature is close to the space dry bulb temperature and the space dew point temperature rises, condensation will occur. These rises in space dew point temperature can occur by virtue of air conditioning equipment cycling off or throttling back, or because of doors being opened or air infiltrating, thus allowing the space dew point temperature to rise above the inside surface temperatures causing condensation. With a properly designed and properly functioning air conditioning system operating within the comfort zone there should be enough leeway between inside surface temperature and space dew point temperature to permit these occurrences without letting the space dew point temperature rise sufficiently to cause condensation.

The mass and color of the construction in humid climates can have a slight influence on the thermal performance of buildings with regard to moisture condensation. Since most buildings in these climates are light in color the majority of the solar heat is reflected, thus tending to keep the exterior surface temperatures relatively cooler. This has the tendency to slightly enhance condensation possibilities. At night when clear skies are present, it is possible for clear sky radiation to cause surface temperatures to drop to as much as 10F below ambient temperatures. Since in humid climates the ambient dew point temperature is usually close to the ambient dry bulb temperature, these drops in surface temperature will cause condensation. While this is a common occurrence, not much can be done about it. The better

insulated the building is, the less tendency there will be for this condensation.

Buildings of light mass construction will generally have the mass temperature close to the ambient temperature depending upon the thermal resistance of the materials of construction. Thus the surface temperature will tend to follow the ambient temperature more closely. In buildings of heavy mass construction there is heat storage within the mass such that the mass temperatures will tend to lag the ambient temperatures. During the diurnal cycles of temperature and sunshine, the mass can influence condensation probability, especially during morning hours. Buildings having heavy massive construction will tend to warm up during the day from solar radiation and cool down slowly at night, thus keeping the mass and surface temperatures above the ambient dew point temperatures. At night, the mass of the building cools down and as the ambient temperature (and dew point) rises in the morning hours, the mass and surface temperatures tend to remain colder, thus providing the opportunity for condensation when the ambient dew point temperature rises sufficiently.

While the mass and color are not of major concern, their performance with respect to moisture condensation should be recognized.

In addition to the thermal performance of the building elements, the configuration of the building must be considered. Since mold growth is dependent upon moisture, temperature and air flow, the configuration of the building can enhance or reduce

the tendency for mold growth. The most significant features that occur are projections from the building and corners, both horizontal and vertical.

Corners in buildings tend to permit the presence of stagnant air, since free air movement cannot occur. These stagnant air pockets occur at such places as projecting columns, projecting sun shading devices and changes in direction of the building walls. In addition, shading devices that are utilized to protect fenestration from solar heat gain also keep the walls that they are shading relatively colder and therefore there is more of a tendency to enhance condensation and mold growth.

With projections such as columns it is reasonable and practical to insulate them on the interior of a building and therefore eliminate the cold radiator effect, thus taking another step towards minimizing the possibility for mold growth even in the presence of stagnant air. However, with horizontal projections from the building used as shading devices this problem cannot be solved so easily, since the horizontal projections are usually structural and part of the floor or roof construction. Hence these projections become cold radiators so that in addition to having low surface temperatures, they also tend to create stagnant air pockets, and mold growth is more prevalent.

Foundation walls are also influenced by stagnant air and a cold radiator effect since they are close to the ground where the minimum air motion occurs. Depending upon the

type of foundation and floor construction the ability to insulate in order to keep the foundation temperature as high as possible should be considered.

#### Moisture Performance

The moisture performance of building materials deals with their ability to restrict the flow of moisture due to differences in vapor pressure and the opportunity for that moisture to condense within the materials forming water. Water vapor will flow through most all building materials without causing damage, providing there is no condensation. The result of this moisture flow in humid climates is that it increases the humidity of the occupied space and the latent cooling load of the space. The significance of moisture condensing within building materials is that it tends to reduce the thermal performance of those materials, aggravating the moisture problem, and can also lead to deterioration of building materials and finishes.

In the absence of specific vapor barriers, the types of building materials utilized are usually highly permeable to moisture flow (the materials have low moisture resistance). Most paints and finishes utilized on buildings tend to have low permeance or high vapor resistance, with a high degree of variability among these finishes and materials. Therefore, it is usually the paints and finishes that become the major determinants of vapor flow through building construction, in the absence of a specific vapor barrier.

While the basic principles of vapor flow through building materials are fairly well known, there remain many questions as to the specific performance of materials in actual buildings, especially in humid climates. Most all of the experimental work that has been done has been on buildings and materials that are utilized in cold climates where the vapor flow is from the inside of the building out. We were unable to find a body of literature that addressed the vapor flow problems in air conditioned buildings in humid climates, thus the specific projections of vapor flow theory remain somewhat open to question.

As dew point temperatures rise, vapor pressures become greater more quickly. Therefore, in humid climates with high ambient dew point temperatures and air conditioned buildings with dew point temperatures in the comfort range, the difference in vapor pressure between indoor and outdoor becomes significantly higher than the differences in vapor pressures experienced in heated (and humidified) buildings in cold climates.

The vapor flow problems in humid climates are further magnified by the fact that vapor flows are usually unidirectional throughout the entire year. In cold climates the direction of vapor flow changes from summer to winter, thus permitting a reversal in the direction of vapor flow and the opportunity for any accumulated moisture to dissipate.

The design of air conditioned buildings in humid climates must therefore consider the constant unidirectional flow of vapor into buildings and permit it to occur without causing damage

to the building and moisture related problems.

The fundamental purpose of a vapor barrier is to restrict the flow of water vapor into a wall (or roof or ceiling) to a rate equal to or less than that which can pass out of the wall. Therefore, vapor barriers do not have to be 100% efficient. The essential criteria is that the vapor resistance of indoor finishes must be less than the vapor resistance of outdoor finishes.

When moisture accumulates in a wall (or roof or ceiling) it means that more vapor is going into the wall than is getting out. In the absence of condensation, this means that the vapor will accumulate at the location having a high vapor resistance, usually the paint or finish.

Air conditioned buildings in humid climates should therefore have materials with high vapor resistance on the exterior and materials with low vapor resistance on the interior.

In order to determine the vapor resistance of materials it is necessary to also consider the occurrence of condensation so that the materials utilized will keep the vapor pressures at a level sufficient to preclude condensation. Figure 6-3 shows a plot of wall moisture flow in a masonry wall have a thermal resistance of 1.11 with still air on both sides and ambient conditions of 80F dry bulb and 80F dew point with a 70F dry bulb room temperature and various room relative humidities. On the assumption that the finishes have infinite permeance, the saturation vapor pressures at various locations in the

wall are shown as a dashed line. The vapor pressures for flow continuity at various indoor relative humidities are shown as solid lines. The circles represent points of condensation at which the saturation vapor pressure equals the vapor pressure for flow continuity. In order to preclude condensation it is necessary to provide some material with a high vapor resistance on the outside such that the saturation vapor pressures are always above the vapor pressures for flow continuity.

The moisture performance of buildings in humid climates is also influenced by infiltration. In order to minimize this problem it is necessary to reduce the amount of unconditioned outside air that is allowed to enter the conditioned space. Any makeup air for exhaust systems should be supplied by an air conditioning system that functions continuously to dehumidify the makeup air and keep its dew point temperature at or below the room dew point temperature. Infiltration through openings in building construction should also be addressed by means of careful detailing, especially at joints and seams. Infiltration occurs around windows and doors, and these should be specified to provide minimum air leakage.

The occupants of the building can influence moisture performance by virtue of their actions in opening windows and doors. Doors in public access spaces should have automatic closers. Where the air conditioning system is unable to maintain comfort conditions the occupants will tend to open windows. Where the reliability of the air conditioning system is such that loss of air conditioning occurs, the occupants will also tend to

open windows in an attempt to achieve comfort. Keeping windows and doors open only aggravates moisture problems.

#### Building Configuration

The architectural configuration of the building can influence the moisture performance of air conditioned buildings in humid climates.

The provision for access to multiple living quarters can be handled either with central double loaded corridors, exterior corridors or none with access gained directly from the exterior. Where there are no corridors and access is gained directly from the exterior, the design of buildings to preclude moisture problems does not pose any questions. The questions arise when considering whether or not interior or exterior corridors should exist and/or be air conditioned.

When corridors are not air conditioned it is essential to not only design the partitions between the corridor and the conditioned spaces as though they were outside walls, but it is also necessary to become concerned about the conditions that exist within the corridor. Such an interior unconditioned corridor must be adequately ventilated with sufficient air motion to preclude air stagnation and the possibility for mold growth. Usually by the time these provisions are made it turns out to be less costly to air condition these corridors. Therefore, we recommend that when corridors are utilized that they be air conditioned unless the walls between the corridors and conditioned spaces are treated as exterior walls and the corridors are adequately ventilated.

There is some question as to the advisability of utilizing entrance vestibules for air conditioned buildings in humid climates. While the use of vestibules may tend to reduce the infiltration associated with the opening and closing of doors, we are unable to predict or calculate the magnitude of the savings in air conditioning that would result from their use. When the air conditioning system is able to maintain comfort conditions within the building, reasonable use of doors should not create moisture problems, providing that the designer has considered both the sensible and the latent heat gain that would result from door opening. Therefore, we are unable to make a specific recommendation to utilize vestibules.

Architectural devices utilized for shading fenestration should be limited to those exposures receiving sunlight and to the shading of the fenestration itself. This will tend to limit the cold radiator effect and limit the shading of walls and the stagnant air pockets that can be created by extensive shading devices. Limiting shading to the fenestration where it benefits the air conditioning will also enable the air flow and solar heat gain on the walls to evaporate whatever moisture does condense and therefore minimize mold growth.

Floor to floor height limitations or guidelines should be evaluated in light of the need for ducted air conditioning systems and their relative ability to provide comfort conditions compared with piped systems which permit lower floor to floor heights but are limited in their ability to provide comfort.

Where low floor to floor heights are desirable or essential and comfort is to be maintained, the only reasonable solution becomes the use of unitary air conditioning equipment such as through the wall units or window type units.

Ventilation above ceilings, especially in multistory buildings, can become a significant concern in air conditioned buildings in humid climates. Using ambient air for ventilation above ceilings in multistory buildings will cause condensation to occur on the cold surfaces of the floor above (and possibly the structure as well) and cause substantial vapor flow into the ceiling and the room below with the consequent saturation of the ceiling materials which causes sagging and eventual failure. While it would be possible to insulate the floors to preclude condensation below, this becomes rather impractical. It is also quite impractical to install vapor barriers on ceilings to preclude vapor flow. These conditions will exist either for natural ventilation or for mechanical ventilation.

The solution to this problem must therefore consider that the space above ceilings is a conditioned space. Either no ceilings should be utilized, or the space above suspended ceilings should be considered as conditioned space and allow for circulation of room air. This means that the walls surrounding spaces above ceilings should be treated as outside walls and sealed carefully to preclude infiltration.

Consideration must be given to the generation of water vapor in toilet rooms and closets. In toilet rooms moisture is

generated by bathing and showering, while in closets it occurs by virtue of damp or wet clothing or other materials being stored. Toilet rooms and closets must be considered as conditioned spaces and provisions made for adequate circulation of conditioned room air.

In toilet rooms, the exhaust registers should be located near the greatest source of moisture vapor, namely the shower or bathtub. Louvered doors should be utilized to permit equalization of vapor pressures and moisture diffusion. Natural ventilation should be prohibited in toilet rooms in air conditioned buildings.

Louvered doors should be utilized in closets in order to permit diffusion of moisture vapor. The tradition of using electric heaters in closets in humid climates need not be followed when louvered doors are utilized since the ambient dew point in closets will be kept at a sufficiently low level.

#### Air Conditioning Systems

The primary concern with air conditioning systems in humid climates is the ability to continuously maintain comfort conditions under all conditions of cooling load. The evaluation, selection and operation of the air conditioning system must consider the ability of that system to meet these requirements.

It is of significance to note that virtually every building with moisture problems in humid climates utilizes fan coil systems, while those buildings utilizing central air systems and unitary systems seem to have far fewer moisture problems.

The reasons for this are inherent in the system concept, especially with respect to the ability of each system to maintain humidity control, and to eliminate condensed moisture from the conditioned space to the maximum extent possible.

Central air handling systems typically have more cooling coil surface area and are thus able to better dehumidify and are more tolerant to variations in chilled water supply temperature. They also do dehumidification centrally and keep the condensate and piping away from the conditioned spaces.

Unitary air conditioning systems operate at lower evaporator temperatures than central systems, especially at light loads, thus giving them much greater dehumidification capability. They also tend to be more reliable in their operation and are not subject to loss of performance due to a malfunction or breakdown of a central plant.

The requirement to have chilled water piping running throughout the building in order to serve room fan coil units creates problems with respect to condensation in and on the piping and its insulation and the conditions that exist in pipe chases and shafts where this piping runs which tends to accelerate moisture problems.

Therefore, air conditioning systems for buildings in humid climates should be able to insure adequate dehumidification under all conditions of load, keep condensate out of the conditioned space to the maximum extent possible, be reliable as possible, be tolerant to variations in chilled water tempera-

tures, avoid having piping in or above occupied spaces and minimize the ability of the occupants to tamper with it.

The types of systems which satisfy these requirements are central air handling systems of either the variable air volume type or the constant volume type with some form of reheat, and unitary systems. With central air handling systems it is desirable to utilize the draw through concept since the fan itself is able to provide some degree of reheat and thus somewhat reduce the saturation of the supply air. The air handling equipment should preferably be located inside the building to preclude the influence of weather and ambient conditions and the associated losses. Adequate provisions should be made for maintenance and service. Supplementary drainage should be provided in the event of drain pan overflows.

The introduction of outside air should be accomplished through a continuously operating air conditioning system and the outside air should be adequate in quantity to slightly pressurize the building under most conditions of wind velocity and exhaust. Preconditioning of outside air in this manner is generally more efficient than allowing makeup air to be infiltrated into the occupied space, since in order to compensate for infiltration loads it is necessary to supply conditioned air at lower humidity.

The introduction of saturated air at variable temperatures into the conditioned space can cause condensation and mold growth. This occurs as changes in load occur when no reheat is present

and the chilled water flow to cooling coils is modulated. When the system is operating under high load conditions the supply air cools off the surfaces in the room immediately adjacent to the supply outlet. As the sensible load is reduced and the chilled water flow is throttled back, the supply air temperature rises but is still saturated and therefore is at a higher dew point than the supply air temperature was and the surface temperature of the materials in the space are. Under these conditions condensation occurs not only on grilles, registers and diffusers, but also on walls and ceilings. This situation is especially prevalent with fan coil units and with central air handling systems that do not employ reheat.

Oversizing of air conditioning systems in humid climates presents a special problem since when operating at less than full load, most air conditioning systems have less latent cooling ability than at full load. In humid climates the sensible cooling loads tend to reduce much faster than latent cooling loads, thus aggravating this problem. The means of overcoming this problem include the use of variable air volume systems and/or reheat in order to continue to dehumidify while maintaining temperature control at the same time.

These kinds of problems exist in some of the more specialized types of buildings utilized by the Navy such as training facilities and controlled temperature and humidity spaces for such things as missile maintenance. In these types of buildings the internal loads are highly variable and it becomes more essential to have an air conditioning system and a

control system that is sufficiently flexible and responsive to wide variations in load in short periods of time while maintaining adequate control over temperature and humidity.

One of the problems noted during this investigation was that of field workmanship, especially in foreign locations where the field labor force is typically not experienced in fabricating and assembling the more complex types of central air conditioning systems and control systems that are utilized in Navy facilities. Even with carefully prepared plans and specifications and with careful supervision, there are just so many situations in which inexperienced field workmanship can contribute to moisture problems in buildings. Some of these areas include the tightness of construction, the ability to vapor seal pipe insulation, the ability to install and calibrate control systems, etc.

Our investigation also showed that the quality of operation and maintenance of air conditioning systems had a significant influence on the ability of those systems to preclude moisture problems. Again, this was more pronounced in foreign locations than in the United States locations since much of that work is done by relatively inexperienced local people.

Thus it becomes incumbent on the designer to anticipate the workmanship, operation and maintenance that these air conditioning systems will experience. The more critical items of concern have been shown to be vapor tightness of pipe insulation, reliability of chilled water plants from the standpoint

of maintaining design chilled water temperature and keeping chillers operating. Alarms for the purpose of alerting the occupants and maintenance personnel to malfunctions would be of assistance in correcting these problems earlier and precluding damage to the buildings.

#### Fan Coil Units

Since the majority of problems with air conditioned buildings in humid climates have occurred in buildings utilizing fan coil unit systems, this discussion will focus on the reasons for those problems. Fundamentally the cause of most of these problems is the inability of fan coil units to adequately control relative humidity within the comfort zone.

Figure 6-4 shows a plot of the relationship between the sensible heat ratio and the entering wet bulb temperature for fan coil units. As the entering wet bulb temperature increases the sensible heat ratio tends to drop, thus making more latent cooling capacity available. However, this assumes that a sensible load exists, which it most often does not.

One of the frequent problems found with fan coil units is that while most of the standard units utilize three row and four row coils, with the light design loads encountered, one and two row coils provide the design rated capacity. The latent cooling performance of one and two row coils is significantly lower than that of three and four row coils, yet in order to meet the design conditions they are satisfactory. Figure 6-5 shows a plot of total and sensible cooling capacity for both

three row and four row coils against chilled water temperature. For a given size fan coil unit the four row coil provides both greater sensible and greater latent capacity. With any number of rows of coil the latent capacity drops off rapidly as chilled water temperatures rise. Where fluctuations exist in chilled water temperatures and/or where chilled water temperatures are unable to be maintained at or near their design conditions, little or no latent cooling load will be accomplished even at full sensible load conditions. As the sensible load drops off, so does the latent capability.

Chilled water flow through fan coil units can have an influence on latent cooling capacity. Figure 6-6 shows a plot of total and sensible cooling capacity against chilled water flow for both 40F entering water temperature and 50F entering water temperature. As the chilled water flow rate is increased the total cooling capacity and the latent cooling capacity increase at a more rapid rate than sensible cooling capacity, thus permitting more latent cooling to be done. As the chilled water temperature rises the total and latent cooling capacities are substantially reduced.

Fan coil unit air flow will influence sensible and latent cooling capacity as well as the total cooling capacity. Figure 6-7 shows a plot of cooling capacity versus air flow for a fan coil unit. As the nominal air flow is decreased, the sensible capacity drops off faster than the total capacity, thus providing relatively more latent cooling capacity, but still not the

latent cooling capacity that was available at 100% nominal air flow. Under conditions of light sensible load reducing the air flow tends to provide slightly more dehumidification at light sensible loads.

Under the most ideal conditions (which hardly ever exist) the best that a fan coil system can do is come close to maintaining temperature and humidity near the fringes of the comfort zone. Under typical conditions of operation in humid climates, fan coil units are unable to maintain comfort conditions. Under these conditions there is no tolerance for the many other problems associated with air conditioned buildings, such as infiltration, moisture flow through the materials, showering, wet clothing, etc.

With the common practice of introducing outside air through the fan coil unit there are additional problems. Unless the fan coil unit is kept operating continuously (which it really can't be) the outside air will not be continuously dehumidified. When the exhaust system is removing more air than the fan coil unit was designed for, more air is brought in through the outside air intake which can influence the thermostatic control, making it more subject to outside air temperature than room temperature, thus causing overcooling of the space.

The use of a separate ducted system for supplying conditioned ventilation air in conjunction with a fan coil unit system aggravates the sensible capacity problems that already exist with fan coil systems.

The chilled water piping systems necessary for fan coil units tend to have problems. Since the piping runs through or above the conditioned spaces, any condensation on the piping causes damage to the space below. Balancing of water flows through the fan coil units becomes a difficult and continuing problem due to the hydraulic complexities of such a large piping network, the number of units, and the sensitivity of the latent capacity of those units to chilled water flows. Also, since most of the piping is small and the pressure variations so great, it is necessary to close off balancing valves to very small openings which promotes clogging, which in turn reduces chilled water flow which in turn reduces latent cooling performance.

None of the methods of control available for fan coil units will insure adequate comfort conditions. Fan control and water control or a combination of both only respond to sensible load and cannot dehumidify unless a sensible load exists, even under the most ideal conditions for fan coil systems. When other problems exist such as chilled water flow, chilled water temperature, infiltration, etc., the inability to dehumidify is almost always worsened rather than improved.

With the inability of fan coil units to achieve comfort conditions the occupants are motivated to attempt such things as overcooling the room, opening windows, jumpering controls, etc., all of which tend to worsen the situation.

Having chilled water piping and cooling coil drain pans in the

occupied space in humid climates creates a situation in which these surfaces are continually wet, thus enhancing the collection of lint and the growth of mold, mildew and scale. The pitch of drain pans is not usually checked unless serious overflow problems occur, thus providing more continuous standing water in the occupied space. Fan coil units become collection devices for debris and items that may be placed on the fan coil units.

Drain pan overflows in unoccupied rooms may go unnoticed for long periods of time causing damage not only in the room in which the pan overflows, but in adjacent rooms and rooms below.

Since the control valves and wiring are located in this moist environment in fan coil units, they have a tendency to corrode and malfunction more frequently.

With all of these problems we can find no justification for utilizing fan coil unit systems in air conditioned buildings in humid climates.

#### Exhaust Systems

Exhaust systems can influence moisture problems in air conditioned buildings to the extent that they remove more conditioned air than is being supplied.

As indicated above, natural ventilation systems should not be utilized in air conditioned buildings.

It was previously indicated that air conditioned buildings

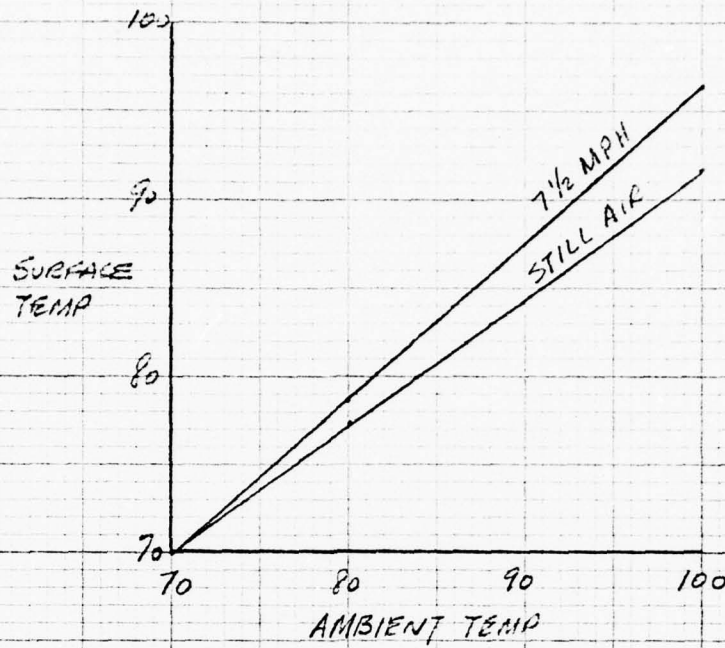
should be pressurized by means of supplying more air than is exhausted. A design decision must be made on whether to use individual exhaust systems or central exhaust systems and the means for controlling them.

From an energy and comfort standpoint it is desirable to have exhaust systems operate only when necessary. In the case of individual exhausts this can be accomplished by having individual switches or by having the exhaust fan operate only when the light is turned on. In the case of central exhaust systems they can be controlled so that they operate only when one or more light switches are turned on. Either the individual or central exhaust system is acceptable, provided that dampers are utilized to preclude air flow while the fans are not running.

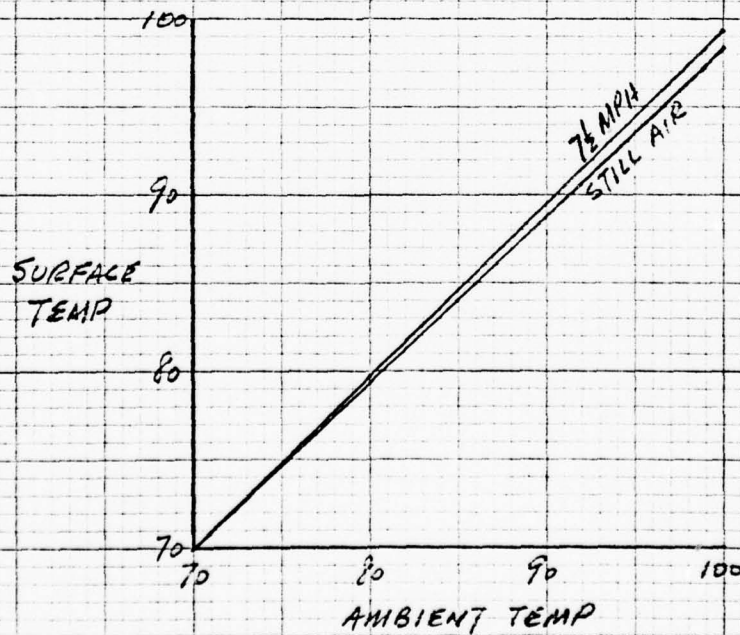
# OUTSIDE WALL SURFACE TEMPERATURES

ROOM TEMP = 70°F

WALL R-1.11

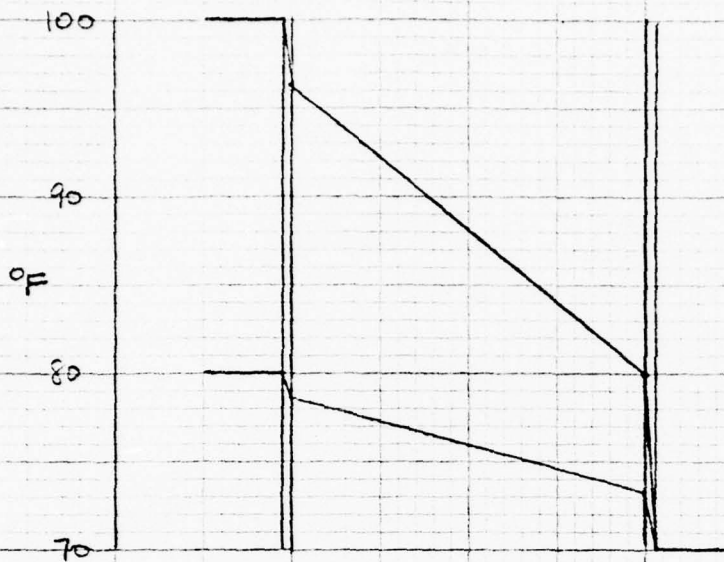


WALL R-10

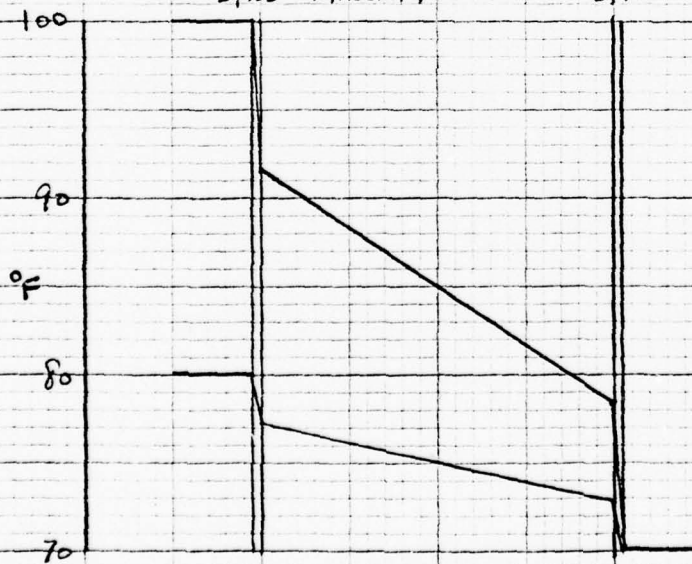


# WALL TEMPERATURES

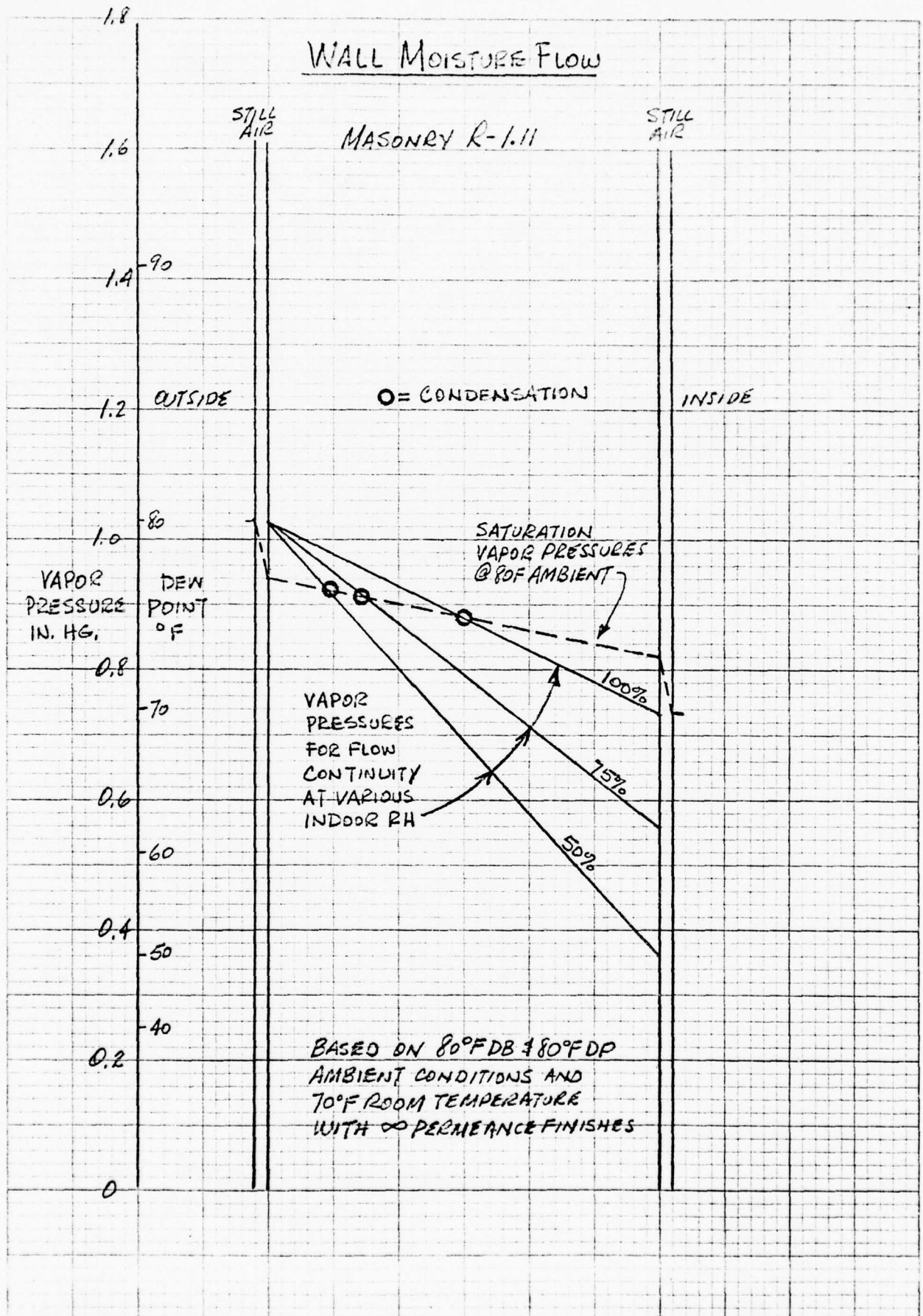
$7\frac{1}{2}$  MPH MASONRY  $R=1.11$  STILL



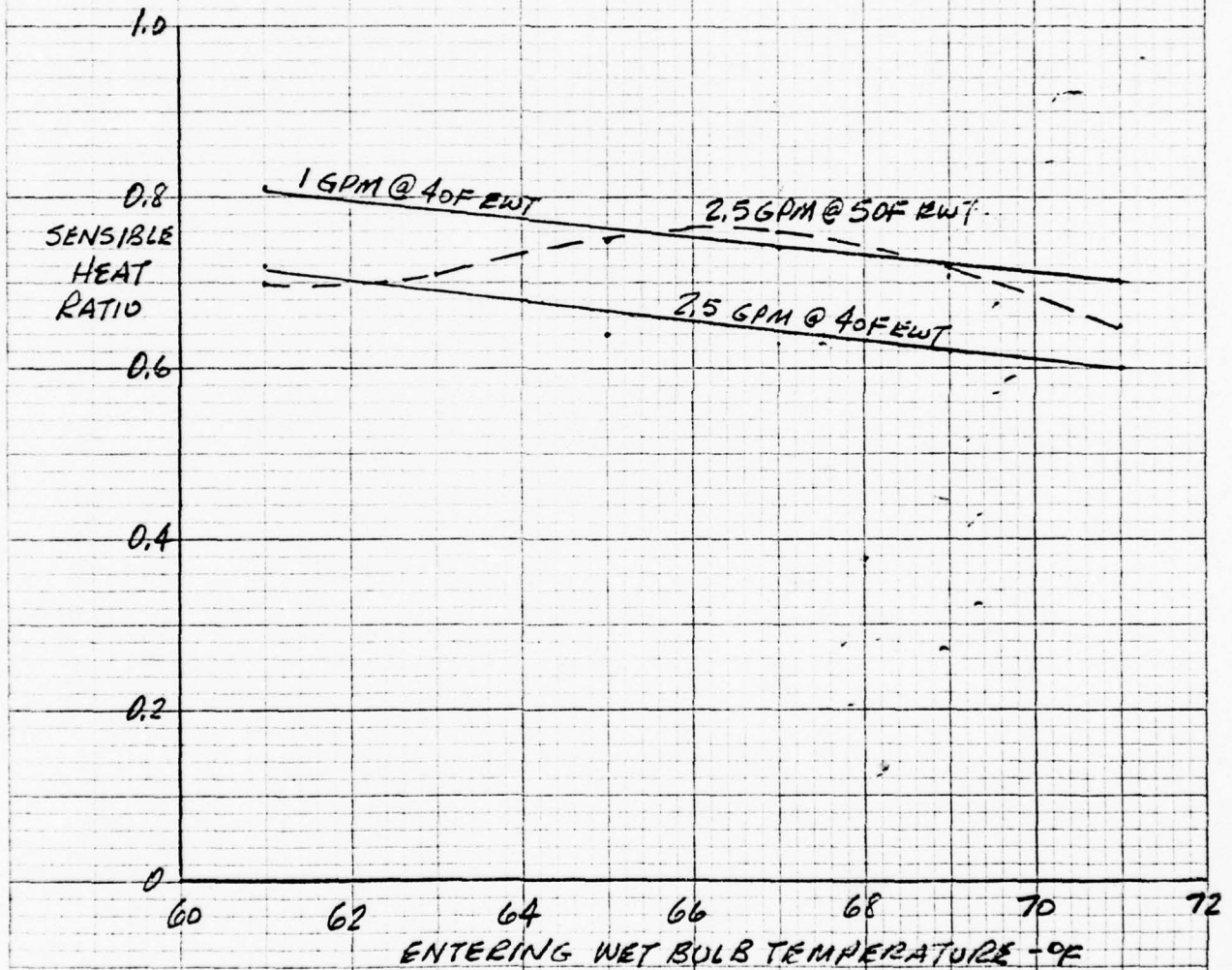
STILL MASONRY  $R=1.11$  STILL



# WALL MOISTURE FLOW



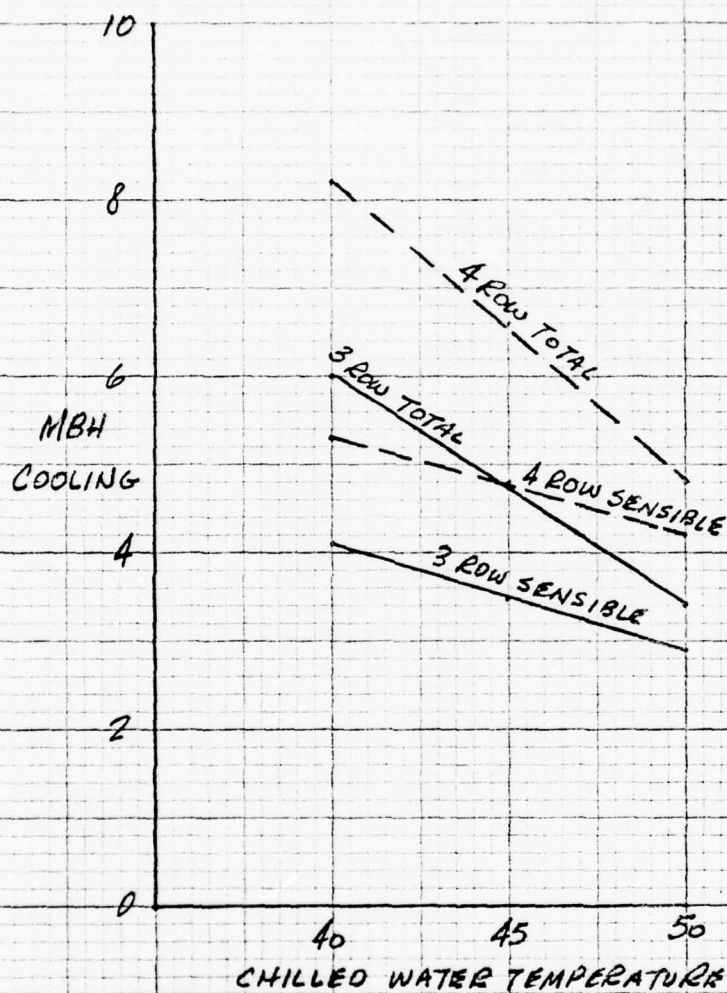
# FAN COIL SENSIBLE HEAT RATIO VS ENTERING WET BULB



BASED ON CARRIER SERIES 42, SIZE 1, 3 ROW COIL  
250 NOMINAL CFM

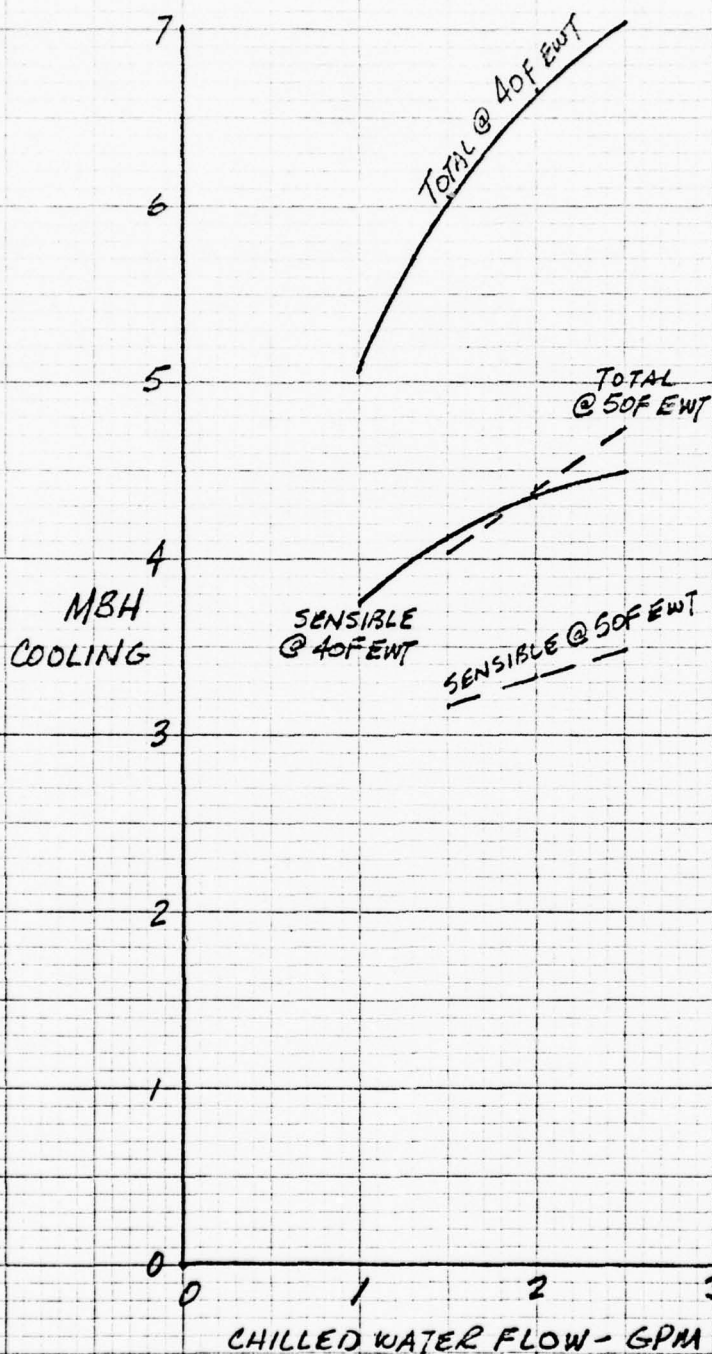
FIGURE 6-4

# FAN COIL COOLING CAPACITY VS ROWS AND WATER TEMP



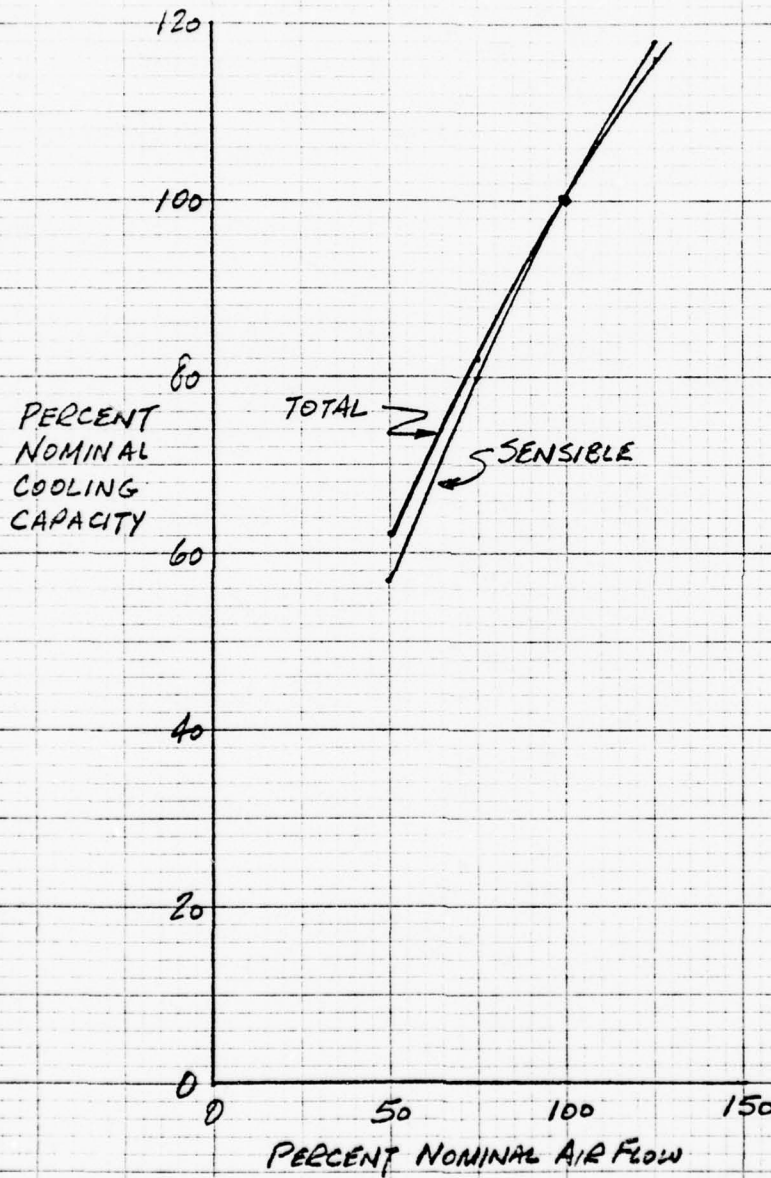
BASED ON CARRIER SERIES 42V, SIZE 2, 200 CFM  
10°F WATER RISE, 80°F/67°F ENTERING

# FAN COIL COOLING CAPACITY VS CHILLED H<sub>2</sub>O FLOW & TEMP



BASED ON CARRIER SERIES 42, SIZE 1, 3 ROW COIL  
250 NOMINAL CFM, 80°F/67°F ENTERING AIR

# FAN COIL COOLING CAPACITY VS VARIATIONS IN AIR FLOW



BASED ON CARRIER SERIES 42, SIZE 2

## CHAPTER 7

### COMPUTER ANALYSIS

#### Purpose

The purpose of this part of the work is to evaluate the performance of an air conditioned building in a humid climate. A series of hour by hour computer analyses were performed to investigate the influence of changes in room temperature, variations in outside air quantity, permeance of the structure and air conditioning system type on air conditioning cooling loads and energy consumption and space comfort conditions.

One unique portion of this work was the consideration of the permeance of the structure since this has never been considered before in any computer analysis.

#### Method

The Ross Meriwether Energy Systems Analysis series of computer programs was utilized for the purpose of performing the evaluations. A description of the programs is included on pages 7A-1 to 7A-2. One floor module of a Welton Becket BEQ with four bedrooms, two bathrooms and a lounge was selected for analysis. The module (considered as a building) was located in Agana, Guam and actual hourly weather data for 1958 was utilized.

The module is 44 by 36 feet and is located at the end of a building and on the top floor. It was oriented in a North South direction. A maximum occupancy of 16 persons was

meance and results in a calculated latent heat gain of only 77 Btu's per hour at design conditions.

Option No. 7 was the high permeance case with unpainted concrete block walls (or concrete block walls painted with a highly permeable paint) and a ceiling with the space above it ventilated to ambient conditions constructed of drywall plus two inches of insulation. The wall had a permeance of 2.4 perms, while the ceiling had a permeance of 26.9 perms. This gave a total latent heat gain of 3,781 Btu's per hour at design conditions.

Option No. 8 consisted of a combination of the most severe conditions considered in the above options. High permeance construction was used with a thermostat setting of 70F and three air changes per hour of outside air.

Options 9A and 9B were the same as the Base Case (Option No. 1) except that the HVAC system type was changed from fan coil units to variable air volume. In both cases the maximum rated air flow of the variable air volume system was assumed to be equal to the air flow of the fan coil units. In Option 9A a minimum air flow setting of 450 CFM was utilized, while in Option 9B a minimum air flow setting of 225 CFM was utilized. At air flows below the minimum setting, reheat is utilized in order to maintain space temperature.

Details of the data used in the various options are shown on pages 7B-1 to 7B-6.

gain due to the permeance of the structure simply raises the average humidity in the space to a somewhat higher level than it already was and does not result in that much additional cooling energy consumption since the fan coil system is unable to remove the humidity that is already there, much less the additional humidity as a result of permeance through the structure. Were another type of HVAC system used which were able to remove the additional moisture, then the cooling energy consumption would have increased more.

Option No. 8 combines the extremes of the previous options with high permeance through the structure, a low thermostat setting of 70F and three air changes per hour of outside air, thus showing a very high cooling energy consumption. Reference to Figure 7-1 shows the plot at three air changes per hour for Options No. 5 and 8 indicating that the slope is to be expected. Projecting the three air change plot to 80F room temperature shows that it crosses the one air change cooling energy consumption plot at about 79F. This indicates that the additional outside air begins to remove more heat gain than it adds when thermostat settings are 79F and higher. This obviously applies only to the fan coil unit system in the building evaluated.

Options 9A and 9B show that the cooling energy consumption for the variable air volume system is higher than for the fan coil unit system. However, the big

difference is that the space conditions are maintained within the comfort chart at all times. The big difference in cooling energy consumption results from the dehumidification of outside air. Even though the capacity of the variable volume system was 1,500 CFM, the maximum requirement during the year in either Option 9A or 9B was just under 900 CFM. In Option 9A with a minimum air flow setting of 450 CFM both the cooling energy consumption and the reheat energy consumption were higher than in Option 9B where the minimum air flow setting was 225 CFM. This would be as expected due to the long hours at light load.

Some further analysis was done of the variable volume system in order to examine the part load conditions. Figure 7-3 shows a rough plot of hours per year versus air flow rate for the variable air volume system. Table 7-3 shows an approximate analysis of the hours per year at various part load conditions for the variable volume system.

TABLE 7-3

<u>VAV SYSTEM AIR FLOW</u>	
<u>% HOURS PER YEAR</u>	<u>% AIR FLOW OR LESS</u>
100	100
75	50
50	33
25	25

Obviously the variable air volume system operates at 100% air flow or less for 100% of the hours in a year. The system

operates at less than 50% air flow for 75% of the hours in a year. It operates at less than 33% air flow for 50% of the hours in a year. It operates at 25% of maximum during 25% of the hours in a year.

In a climate such as Guam the part load performance thus becomes significant since the system operates at less than half load for more than three quarters of the hours in a year.

The preceding analysis is based upon the maximum air flow rate for the variable volume system being exactly what the maximum annual loads require. However, in most instances the design rated air flow is substantially in excess of the maximum experienced air flow. As a result there will be many, many more hours per year in which the variable air volume system will be operating at light part loads. The minimum air flow setting of the variable volume system thus becomes critical when considering the quantity of reheat energy that will be required.

Sample computer printouts for the various options are shown on pages 7C-1 to 7C-10.

It should be realized that the preceding evaluations were based upon a module with a number of rather specific assumptions as to location, orientation, construction, etc. Certainly, changes in any of these assumptions will change the results to some degree. However, the basic conclusion still

exists that regardless of system type, in a tropical humid climate the HVAC system operates at substantially less than half capacity for the majority of the hours in a year.

Figure 7-4 shows a load duration curve for the fan coil system.

All options were based upon an end top floor module in a Welton Becket standard design. Were an intermediate lower floor module to be evaluated, the external influences would have been smaller and in all probability there would have been even more hours at lighter loads.

The assumptions that were made regarding the internal heat gains can and will vary depending upon the living habits of the occupants. These internal heat gains could be both higher and lower than those assumed which would change the magnitude of the results, but not the character.

#### Conclusions

While the fan coil system is able to maintain space temperatures at any desired setting, it is unable to control humidity. The dehumidification which does result is insufficient to obtain space conditions anywhere near the comfort zone.

While the variable volume system uses more cooling energy than the fan coil system at the same room temperature, it consumes less energy than the fan coil system operated at lower temperatures and is able to provide space conditions within the comfort zone at all times as indicated in Figure 7-5.

TABLE 7-1

OPTIONS EVALUATED

<u>OPTION</u>	<u>DESCRIPTION</u>					
1	No Permeance	75F Thermostat	1 Air Change	Outside Air	Fan Coil Units	
2	No Permeance	70F Thermostat	1 Air Change	Outside Air	Fan Coil Units	
3	No Permeance	80F Thermostat	1 Air Change	Outside Air	Fan Coil Units	
4	No Permeance	75F Thermostat	2 Air Change	Outside Air	Fan Coil Units	
5	No Permeance	75F Thermostat	3 Air Change	Outside Air	Fan Coil Units	
6	Low Permeance	75F Thermostat	1 Air Change	Outside Air	Fan Coil Units	
7	High Permeance	75F Thermostat	1 Air Change	Outside Air	Fan Coil Units	
8	High Permeance	70F Thermostat	3 Air Change	Outside Air	Fan Coil Units	
9A	No Permeance	75F Thermostat	1 Air Change	Outside Air	Variable Volume	450 CFM Min
9B	No Permeance	75F Thermostat	1 Air Change	Outside Air	Variable Volume	225 CFM Min

TABLE 7-2  
COOLING TON HOURS

<u>OPTION</u>	<u>DESCRIPTION</u>	<u>TON HOURS/YR</u>	<u>% OF ERE-1</u>
ERE-1	NO PERM 75F 1AC FC	10,119	100
ERE-2	NO PERM 70F 1AC FC	15,611	154
ERE-3	NO PERM 80F 1AC FC	4,808	48
ERE-4	NO PERM 75F 2AC FC	12,629	125
ERE-5	NO PERM 75F 3AC FC	15,149	150
ERE-6	LO PERM 75F 1AC FC	10,128	100
ERE-7	HI PERM 75F 1AC FC	10,549	104
ERE-8	HI PERM 70F 3AC FC	26,908	266
ERE-9A	NO PERM 75F 1AC VAV 30%	16,029	158
ERE-9B	NO PERM 75F 1AC VAV 15%	13,834	137

LEGEND

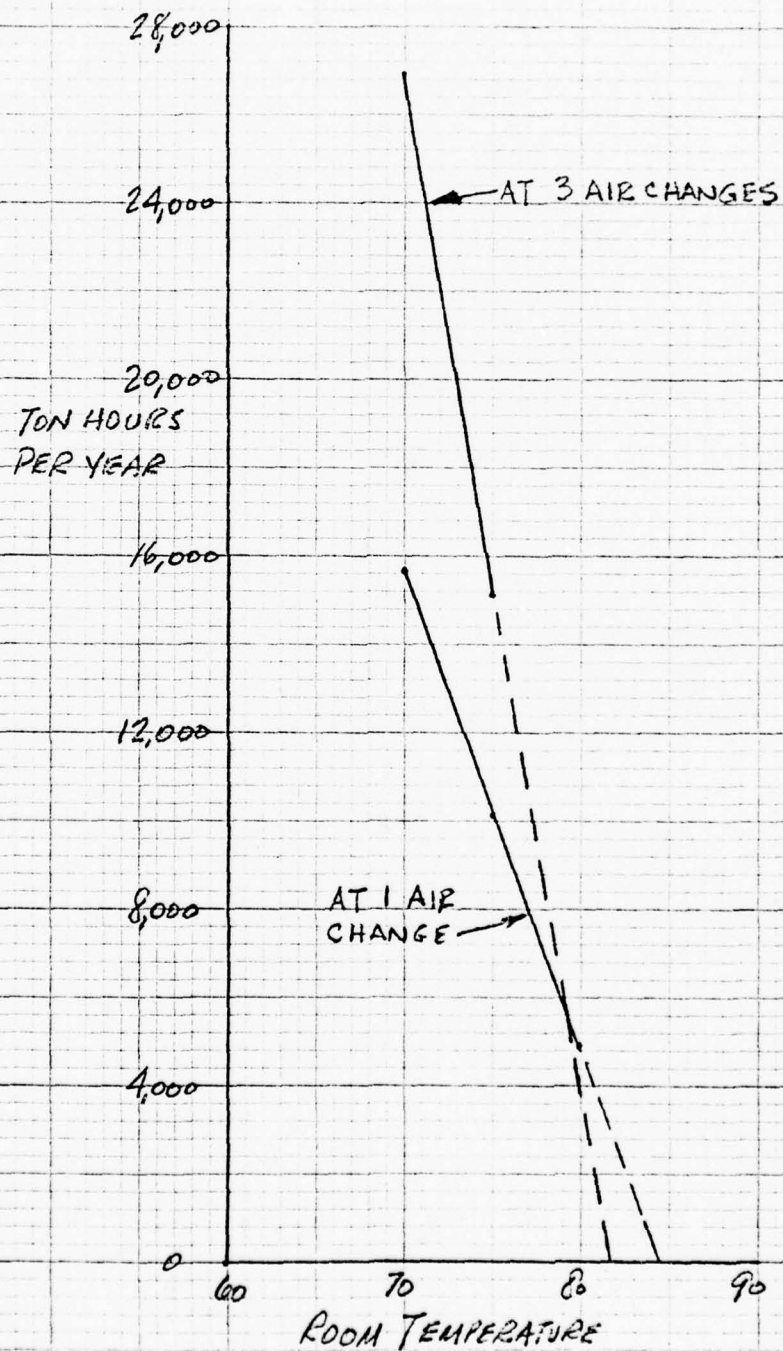
PERM: NO = NONE; LO = LOW; HI - HIGH

AC: AIR CHANGES/HOUR EXHAUST

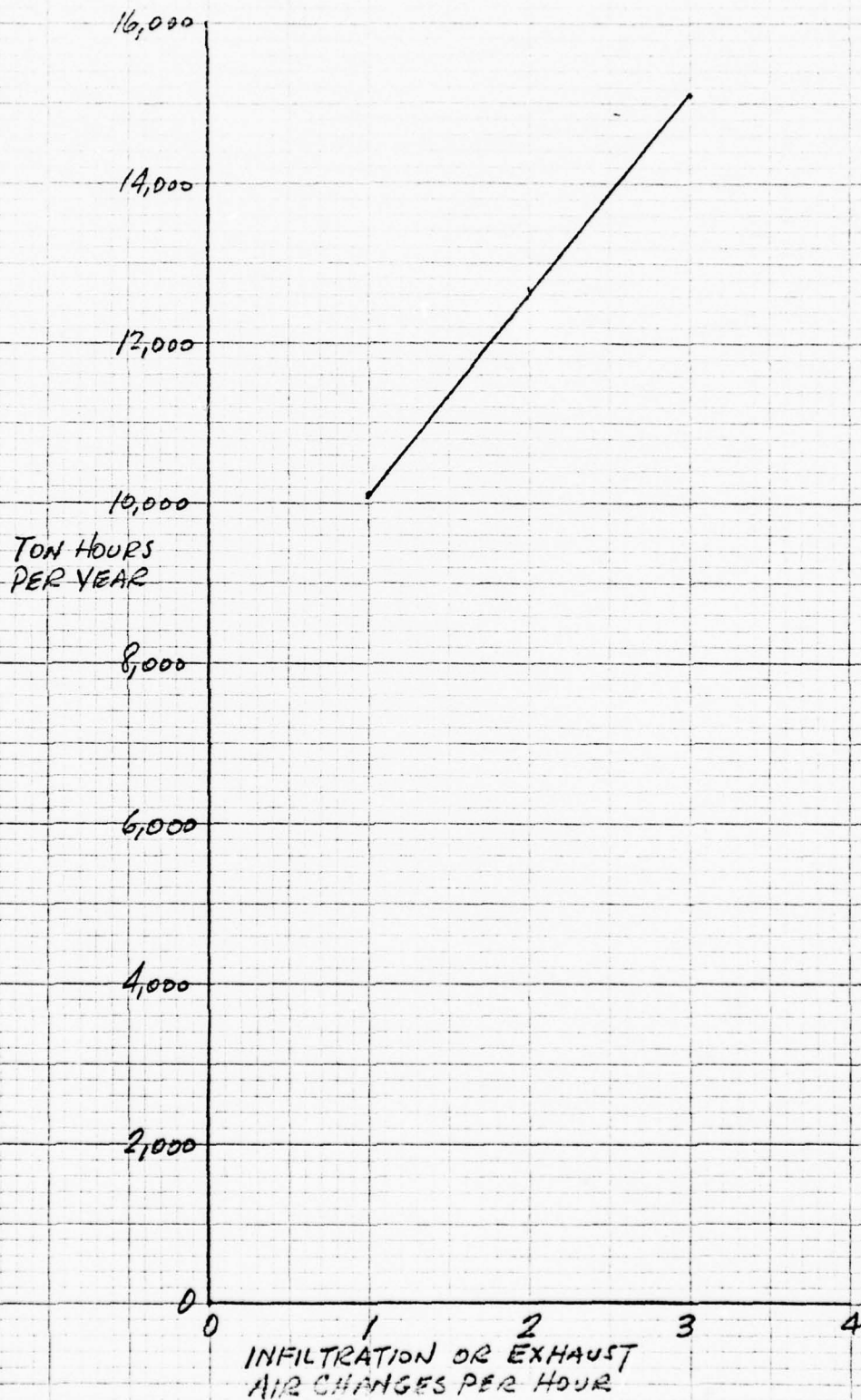
FC: FAN COIL SYSTEM

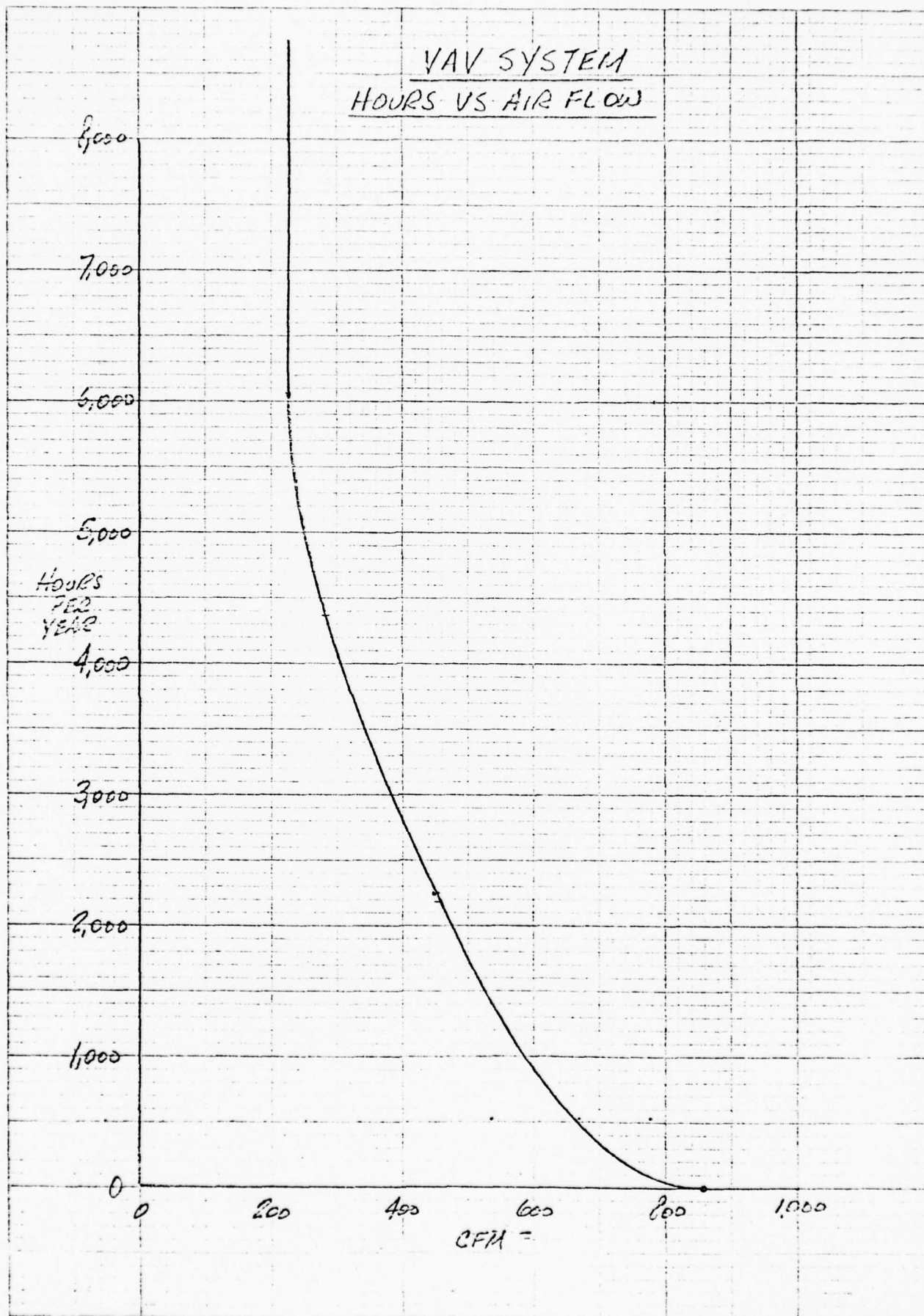
VAV: VARIABLE AIR VOLUME SYSTEM; 30% & 15% MINIMUM AIR FLOW

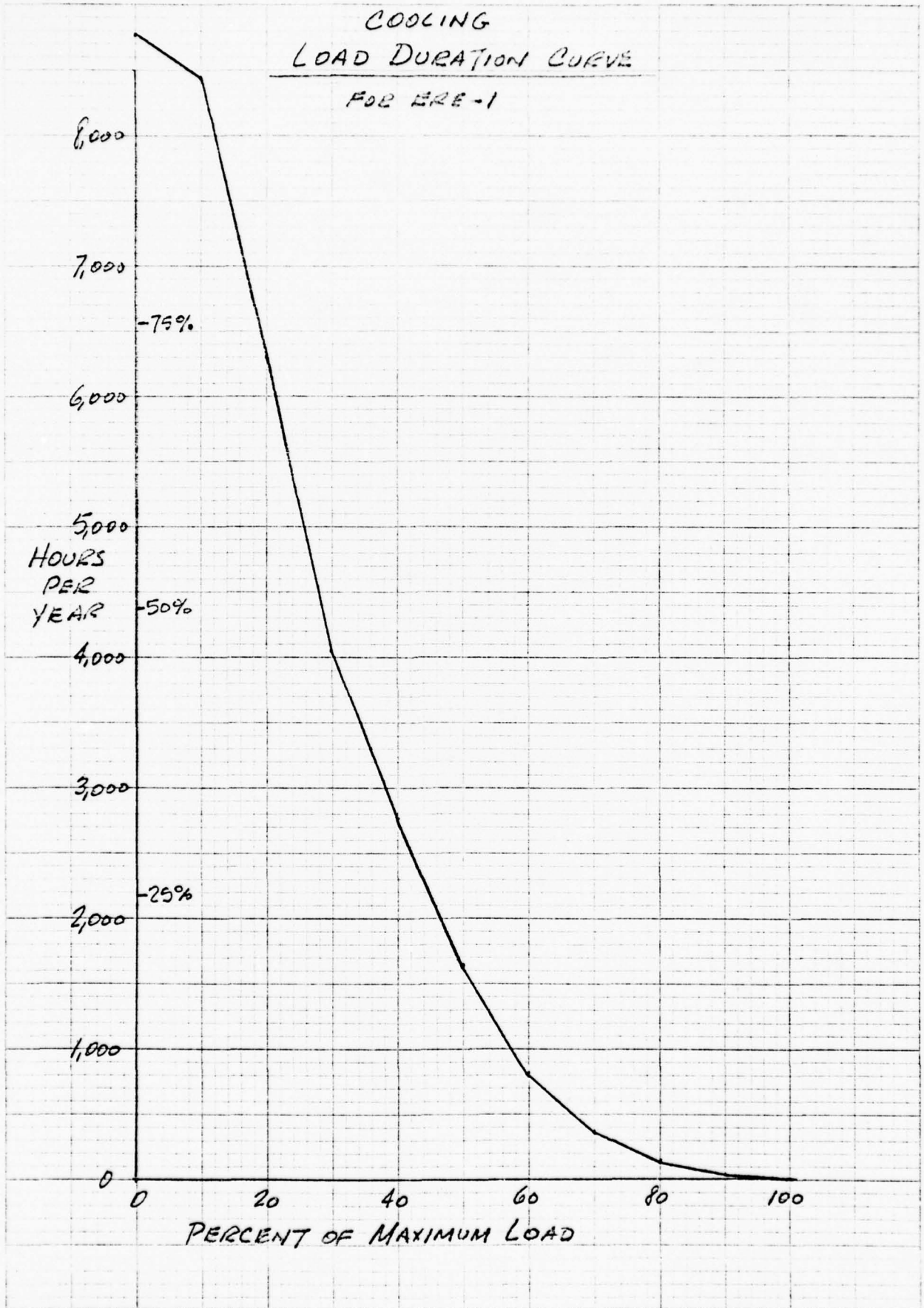
# COOLING ENERGY VS ROOM TEMPERATURE



# COOLING ENERGY VS EXHAUST (INFILTRATION) RATE







# ASHRAE PSYCHROMETRIC CHART NO. 1

NORMAL TEMPERATURE  
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY  
COPYRIGHT 1963  
AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.

## MAXIMUM ROOM HUMIDITY

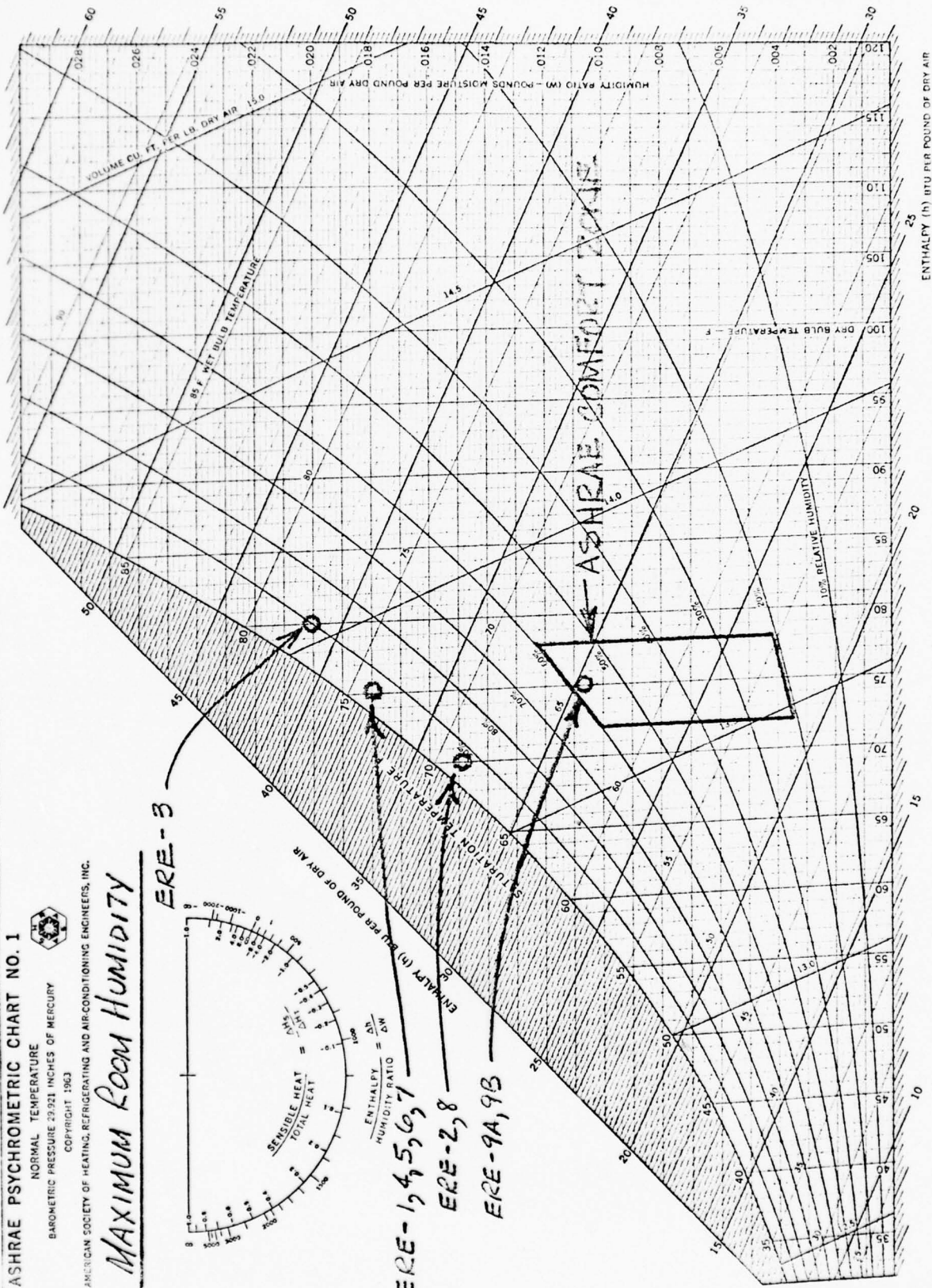
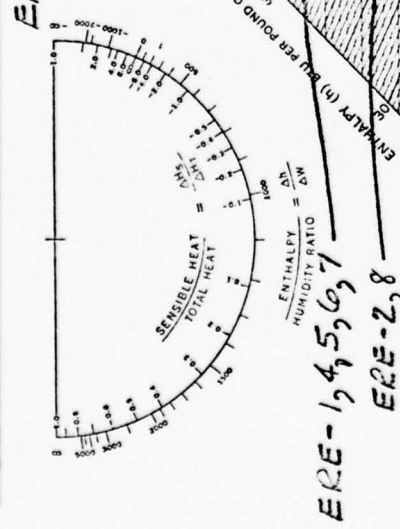


FIGURE 7-5

DESCRIPTION OF THE PROGRAMS IN THE  
ENERGY SYSTEM ANALYSIS SERIES

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Energy Requirements Estimate (ERE) - this program uses design point thermal and base electric load components, occupancy and operational schedules, and actual hourly weather data to find the hour-by-hour energy requirements for a building or building section during a typical year's operation. The program provides for the simulation of many types of air-side systems (such as dual-duct, terminal reheat, induction or fan-coil, variable volume, and simple single-duct). The system simulation allows control temperature reset, scheduled outside air quantities, outside air economizer operation, and many other operating and control features. An output tape with hour-by-hour values of thermal and base electric load is used as an input to the equipment simulation program. In addition to the printed output illustrated, the program also provides detailed system information at the monthly peak heating and cooling conditions and for as many other operating hours as is desired.

Total Coincident Requirement (TCR) - this program sums the hour-by-hour loads of each building or section (from multiple ERE output tapes) to find total system loads and peak simultaneous loads with actual diversity. A provision is included for a multiplier for each building or section so that an entire complex can be constructed from a few basis ERE runs. A printout of the number of operating hours at ten percent increments of load is shown to assist the user in optimum machine size selection.

Equipment Energy Consumption (EEC) - this program simulates the performance of the various pieces of equipment in a given system as they respond to the loads imposed by the building's air-side system to find monthly and annual input of all energy forms to each system. The equipment can be grouped in any manner to represent all types of systems from conventional heating and cooling, to on-site electrical generation with heat recovery, to all electric, to central plants, to purchased chilled water and steam. Energy sources may be gas, electricity, or any other fuel specified by the user. The program permits the user to specify all equipment capacities, part-load operating data, method of equipment operation, and accessory equipment operating techniques.

In addition to the summary printout of monthly and annual utility demands and consumptions illustrated here, the program also shows operating and full-load hours for each machine, recoverable heat utilization, and a breakdown of the energy use by categories.

Monthly Utility Costs (MUC) - this program matches monthly energy consumption and demand values for each system to the appropriate local utility rate schedules (including purchased chilled water and steam rates, if applicable) to find the monthly and annual cost of supplying energy for the typical year's operation of each system. The program is structured so that the features of each rate are entered as input data. This, along with special keys that describe how the rate is to be applied, enables the user to enter almost any type of utility rate schedule. Summer and winter seasonal rates may also be used in the same system.

The printout includes the monthly and annual costs for each system as well as the average utility cost and the unit cost based on floor area. The program also sums all energy costs into a total utility cost for each system.

Economic Comparison of Systems (ECS) - this program combines typical-year energy costs and other annual operating costs with initial investment and the associated owning cost factors to find the total owning and operating costs of each system year-by-year for any period up to 30 years. Annual utility costs and other operating costs can be independently escalated each year by a percentage supplied by the user. The initial investment may be divided into two segments with different depreciation periods, and a provision exists for two additional reinvestments (for equipment replacement or staged projects) which can be on a recurring basis. In addition to straight cashflow and a discounted cashflow for each system on an independent basis, a comparison can be made of each system to the lowest first cost system to show the net savings of reduced operating costs compared to higher owning costs.

The illustrated printout is the total owning and operating cashflow for a given system. The comparative analysis printout is similar in format, but also gives a value of discounted rate of return on the differential first cost of the given system over the base system.

ross f. meriwether & associates, inc.  
1600 n. e. loop 410 512 824-5302  
san antonio, texas 78209

ERE  
ENERGY REQUIREMENTS ESTIMATE PROGRAM

Lawrence G. Spielvogel, Inc.  
Consulting Engineers  
Wyncote House Wyncote, Pa. 19095  
Phone 215 887-5600

CARD 1 - LABEL (THIS INPUT CARD IS REQUIRED, EVEN IF BLANK)

Building or Section Identification Label

NAVY MOISTURE STUDY 1958 AGANA GUAM NO PERM 75F IAC INFIL FC ERE 1

NOTE: ▽ indicates right-indexed integer entry

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## ENERGY REQUIREMENTS ESTIMATE PROGRAM

Sheet 2 ERE 1-8

CARD 2 - INPUT KEY AND MAXIMUM VALUES

(THIS INPUT CARD IS REQUIRED)

No. of day types		No. of a. b. temp. sch.		No. of percentage		No. of variation profile lines		System type (1)		Addit. syst. data (1=yes)		Solar data key (2)		Air conditioned floor area, SQ. FT.		Reference solar load, MBH		16 People		Lights		Equip.		Miscellaneous		Maximum process heat loads, MBH		Maximum base electric load, KW		On with H/C (3)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1		20	11											1584.	10.4	7.2	50.	61.	34												

- (1) 0 = no excess cooling or reheating, demand coil leaving temperatures  
 1 = terminal reheat with scheduled cold coil discharge temp during cooling  
 2 = terminal reheat with scheduled cold coil discharge temp during cooling or heating  
 3 = induction or fan-coil type system with scheduled primary air temperature  
 4 = terminal reheat with cold coil discharge temp set by maximum demand of any section  
 5 = dual-duct with scheduled hot and cold deck temperatures  
 6 = dual-duct with deck temperatures set by greatest demand  
 7 = variable volume system for solar and internal, with separate single-duct system to offset transmission  
 8 = standard variable volume system  
 9 = two duct system (cold duct and bypass duct)  
 A = variable volume/dual duct (change occurs at min % of max airflow)  
 blank = unit ventilation similar to type 0 except latent load is proportional to sensible load.

- (2) 0 = 13 solar values per day, 1 = 24 solar values per day on weather tape,  
 2 = 24 solar values per day from cards (skip 13-hr solar data on weather tape), 3 = 24 solar values per day from LU3 in BCD card images (skip 13-hr solar data on weather tape)  
 4 = no solar on weather tape. Read solar from LU3 in BCD card images.  
 SPECIAL: to have the program only read, print, and unitize the input data, enter a "9". Weather tape and output tape need not be specified in control cards.  
 (3) for VAV systems, fan KW scaled as an exponential function of airflow ratio:  
 key of 1 = exponent of 3.0  
 2 = 2.5  
 3 = 2.0  
 4 = 1.5  
 5 = 1.0  
 6 = 0.5  
 9 = profile 22 (Card type 8); % fan KW vs % airflow

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7B-1

## ENERGY REQUIREMENTS ESTIMATE PROGRAM

Sheet 2

EER 1

## CARD 2 - INPUT KEY AND MAXIMUM VALUES

(THIS INPUT CARD IS REQUIRED)

No. of day types No. of 13-hr. time slots No. of 24-hr. time slots No. of percentage variation profile lines System type (1) Add'l. sys. data (2) Sys. data key (3)		Air conditioned floor area, SQ. FT.	Reference solar load, MBH	Maximum internal loads										Maximum process heat loads, MBH				Maximum base electric load, KW			On with H/C (3)
				16 People		Lights		Equip.		Miscellaneous						Source A	Source B	Source C FAN			
				Total load MBH	% latent	Total load MBH	% direct to R/A	% re- usable for reheat	MBH	Total load MBH	% latent	May be indirect- fired	Must be direct- fired								
1		2	1	1584	10.4	7.2	50.6	34											0.8	1	

- (1) 0 = no excess cooling or reheating, demand coil leaving temperatures  
 1 = terminal reheat with scheduled cold coil discharge temp during cooling  
 2 = terminal reheat with scheduled cold coil discharge temp during cooling or heating  
 3 = induction or fan-coil type system with scheduled primary air temperature  
 4 = terminal reheat with cold coil discharge temp set by maximum demand of any section  
 5 = dual-duct with scheduled hot and cold deck temperatures  
 6 = dual-duct with deck temperatures set by greatest demand  
 7 = variable volume system for solar and internal, with separate single-duct system to offset transmission  
 8 = standard variable volume system  
 9 = two duct system (cold duct and bypass duct)  
 A = variable volume/dual duct (change occurs at min % of max airflow)  
 blank = unit ventilation similar to type 0 except latent load is proportional to sensible load.

- (2) 0 = 13 solar values per day, 1 = 24 solar values per day on weather tape,  
 2 = 24 solar values per day from cards (skip 13-hr solar data on weather tape), 3 = 24 solar values per day from LU3 in BCD card images (skip 13-hr solar data on weather tape)  
 4 = no solar on weather tape. Read solar from LU3 in BCD card images.  
 SPECIAL: to have the program only read, print, and unitize the input data, enter a "9". Weather tape and output tape need not be specified in control cards.  
 (3) for VAV systems, fan KW scaled as an exponential function of airflow ratio:  
 key of 1 = exponent of 3.0  
 2 = 2.5  
 3 = 2.0  
 4 = 1.5  
 5 = 1.0  
 6 = 0.5  
 9 = profile 22 (Card type 8); % fan KW vs % airflow

08-01-77

## ENERGY REQUIREMENTS ESTIMATE PROGRAM

Sheet 3 EER 1-9

CARD 3 - SOLAR PERCENTAGES, SYSTEM CAPACITIES, SHUTOFF TEMPERATURES, AND PRIMARY FUEL INTERRUPTION DATA  
(THIS INPUT CARD IS REQUIRED, EVEN IF BLANK)

Solar area percentages for each facing direction (0 - 100)								Time of ref solar load		Space heating system capacity, MBH	Cooling system capacity, TONS	Heating system shutoff temp.	Cooling system shutoff temp.	Primary fuel interruption temperature, °F	Interruption delay, %	No. of days of primary fuel interruption
D1	D2	D3	D4	D5	D6	D7	D8	Horiz	Shade	Month	Hour					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
40				60						12	12	10		4.0		

- \* Each field corresponds to the order in which the solar table directions are arranged. D1, D2, etc. can be any desired direction but will correspond to the 1st direction, 2nd direction, etc., used in creating the 8 vertical faces in the solar tables. Horizontal is always direction 9, and diffuse only (shade) is always direction 10.  
 If any values are entered, their sum must always equal 100.

- \*\* No. of degrees above interruption temperature before primary fuel back "on".

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7B-2

## ENERGY REQUIREMENTS ESTIMATE PROGRAM

CARD 4 - HEATING/COOLING DATA (THIS INPUT CARD IS REQUIRED, EVEN IF BLANK)

Heating Data												Cooling Data											
Thermostat settings		Ambient design		Design transmission loss, MBH	Hot deck temperature schedule, F				Thermostat settings		Ambient design		Design transmission gain, MBH	(5)		Primary cold coil humidity ratio (lb/lb)	Secondary (or max) supply air temp, F	Secondary cold coil humidity ratio	Return air transmission gain at summer design, MBH	Return air solar gain at summer design, MBH	(6)	Heat storage factor, BTU/F-SF. (7)	Sta. loss (8)
Dry bulb, F	Dew point, F (1)	Dry bulb, F	Dew point, F		Upper ambient temp.	Hot deck temp. at temp.	Lower ambient temp.	Hot deck temp. at temp.	Lower ambient temp.	Dry bulb, F (3)	Dew point, F (4)	Dry bulb, F		Dew point, F	Primary supply air temp, F								
75.		74.	45.	0.66					75.		86.	78.	7.24				70				1.2		

- (1) Leave blank if no humidification is used.
- (2) Enter value here with Type 3 system to allow heating to raise mixed air temp to scheduled supply temp.
- (3) Use a minus sign (-) to show separate thermostat from heating thermostat when the two temperatures are different.
- (4) If a value is entered here, dehumidification control will be used with demand type systems (0, 4, and 6), or with systems having reset supply temp.
- (5) Use temp downstream of the supply fan for drawthru type systems. Use a minus sign (-) with the nominal supply temp to signify a fixed temperature coil for Type 3 system. This temp will control the cold coil even if a reset (reheat) is used on Card 5. Cold coil will be shut off when ambient is below economizer lower limit (cols. 53-55, Card 5).
- (6) Use a minus sign (-) with this temperature to signify a drawthru system.
- (7) If left blank, default is 20.14 BTU/F-SQ. FT. (based on a density of 100 LBS/SQ. FT. and an average specific heat of 0.2 BTU/F-LB). If only density or specific heat is known, prorate the 20.14 value using known values.
- (8) 0 = 3 hr. spread, 1 = 5 hr., 2 = 7 hr., 3 = 9 hr.

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Sheet 4 FEE 7

## ENERGY REQUIREMENTS ESTIMATE PROGRAM

CARD 4 - HEATING/COOLING DATA (THIS INPUT CARD IS REQUIRED, EVEN IF BLANK)

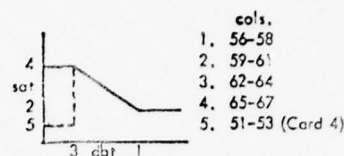
Heating Data												Cooling Data											
Thermostat settings		Ambient design		Design transmission loss, MBH	Hot deck temperature schedule, F				Thermostat settings		Ambient design		Design transmission gain, MBH	(5)		Primary cold coil humidity ratio (lb/lb)	Secondary (or max) supply air temp, F	Secondary cold coil humidity ratio	Return air transmission gain at summer design, MBH	Return air solar gain at summer design, MBH	(6)	Heat storage factor, BTU/F-SF. (7)	Sta. loss (8)
Dry bulb, F	Dew point, F (1)	Dry bulb, F	Dew point, F		Upper ambient temp.	Hot deck temp. at temp.	Lower ambient temp.	Hot deck temp. at temp.	Lower ambient temp.	Dry bulb, F (3)	Dew point, F (4)	Dry bulb, F		Dew point, F	Primary supply air temp, F								
75.		74.	45.	0.66					75.		86.	78.	7.24	55.62							1.2		

- (1) Leave blank if no humidification is used.
- (2) Enter value here with Type 3 system to allow heating to raise mixed air temp to scheduled supply temp.
- (3) Use a minus sign (-) to show separate thermostat from heating thermostat when the two temperatures are different.
- (4) If a value is entered here, dehumidification control will be used with demand type systems (0, 4, and 6), or with systems having reset supply temp.
- (5) Use temp downstream of the supply fan for drawthru type systems. Use a minus sign (-) with the nominal supply temp to signify a fixed temperature coil for Type 3 system. This temp will control the cold coil even if a reset (reheat) is used on Card 5. Cold coil will be shut off when ambient is below economizer lower limit (cols. 53-55, Card 5).
- (6) Use a minus sign (-) with this temperature to signify a drawthru system.
- (7) If left blank, default is 20.14 BTU/F-SQ. FT. (based on a density of 100 LBS/SQ. FT. and an average specific heat of 0.2 BTU/F-LB). If only density or specific heat is known, prorate the 20.14 value using known values.
- (8) 0 = 3 hr. spread, 1 = 5 hr., 2 = 7 hr., 3 = 9 hr.

01-30-76

7B-3

## ENERGY REQUIREMENTS ESTIMATE PROGRAM



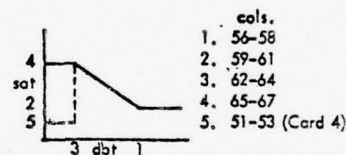
CARD 5 - AIRFLOW DATA (THIS INPUT CARD IS REQUIRED, EVEN IF BLANK)

Supply airflow, CFM	Maximum cold deck airflow, CFM (1)	Maximum hot deck airflow, CFM (1)	Maximum outside airflow, CFM	Minimum outside airflow, cooling cycle, CFM (2)	Minimum outside airflow, heating cycle, CFM (2)	Minimum outside airflow, unoccupied ("shutoff"), CFM	Upper temp. limit for econ, F (3)	Lower temp. limit for econ, F	Cold (Supply) Air Temp Reset (4)	(5)	Outside Air/ Exhaust Air Heat Recovery Efficiencies Sens. (0-99) Latent (0-99)
1500.											

- (1) Applies to dual-duct systems (Types 5 or 6) and to two duct system (Type 9). For a Type A system, max. cold & hot deck cannot exceed cols. 71-72 times cols. 1-7.  
 (2) To get a scheduled outside airflow, enter value of O/A to which profiles apply under min O/A during heating and cooling, and enter desired profile numbers for O/A in cols. 71-72 on Card 10.  
 (3) A minus sign (-) preceding this entry will permit the economizer to operate only when the enthalpy of the outside air is equal to or below that of the return air stream.  
 (4) Use a minus sign (-) with this temp to signify a changeover system, with supply air temp reset to value in cols. 51-53, Card 4 when ambient falls below value in cols. 62-64 on this card.  
 (5) Unoccupied hours are signified by a setback time schedule, even if no setback temperature schedule is used.

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## ENERGY REQUIREMENTS ESTIMATE PROGRAM



CARD 5 - AIRFLOW DATA (THIS INPUT CARD IS REQUIRED, EVEN IF BLANK)

Supply airflow, CFM	Maximum cold deck airflow, CFM (1)	Maximum hot deck airflow, CFM (1)	Maximum outside airflow, CFM	Minimum outside airflow, cooling cycle, CFM (2)	Minimum outside airflow, heating cycle, CFM (2)	Minimum outside airflow, unoccupied ("shutoff"), CFM	Upper temp. limit for econ, F (3)	Lower temp. limit for econ, F	Cold (Supply) Air Temp Reset (4)	(5)	Outside Air/ Exhaust Air Heat Recovery Efficiencies Sens. (0-99) Latent (0-99)
1500.			2100.	2100.	2100.						

- (1) Applies to dual-duct systems (Types 5 or 6) and to two duct system (Type 9). For a Type A system, max. cold & hot deck cannot exceed cols. 71-72 times cols. 1-7.  
 (2) To get a scheduled outside airflow, enter value of O/A to which profiles apply under min O/A during heating and cooling, and enter desired profile numbers for O/A in cols. 71-72 on Card 10.  
 (3) A minus sign (-) preceding this entry will permit the economizer to operate only when the enthalpy of the outside air is equal to or below that of the return air stream.  
 (4) Use a minus sign (-) with this temp to signify a changeover system, with supply air temp reset to value in cols. 51-53, Card 4 when ambient falls below value in cols. 62-64 on this card.  
 (5) Unoccupied hours are signified by a setback time schedule, even if no setback temperature schedule is used.

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[illegible]

- (1) Caution: Normally not used. Use only if special control overrides O/A damper to increase cooling.
- (2) 0 = off when heating system is off  
1 = on at all times  
2 = primary fan off when heating/cooling system is shut off, but secondary coils remain on.  
3 = fan off, secondary coils only hold setback temp (load heating system shutoff).  
5 = during normal operation, suppl. heat is net (oy face) of solar and transmission combined.
- (3) If this field is used, entries must also be made in cols. 66-69, even if the same as in cols. 4-9, Card 4.
- (4) To be used only with variable outside air dampers (economizer cycle). If key = 2, spray used even on min outside air, reheat required but no humidification process load.  
0 = on/off as required  
1 = always on  
2 = fan off when in floating temp "dead band"  
3 = fan on unless both heating and cooling off or setback (also enter outside air shutoff).  
4 = heating and cooling systems are off with fan off in accordance with shutoff temperatures specified on card 3.
- (6) 0 = constant infiltration  
1 = infiltration only when fans are off  
2 = proportional to ambient, always on  
3 = proportional to ambient, on when fans off  
7 = profile 21 (infiltration vs. ambient DBT) with min % if room temperature is less than thermostat setting minus 0.5  
8 = profile 21 (infiltration % vs. ambient DBT).
- (7) 0 = do not convert heating loads to elec.  
1 = convert supplemental heating loads to elec.  
2 = convert secondary coil (only) heating loads to elec.
- (8) 0 = apply percentages to indirect process  
1 = apply percentages to direct process  
2 = ground temperature schedule to be used with negative misc. load.

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Sheet 8 ERE 1-9

(This Input Card May be Omitted if 0 or Blank on Card 2, Cols. 4 - 5)

Percentage of Maximum (0 - 100) and Hours of Duration (1 - 24) Beginning with Midnight

[illegible]

\* If col. 80 on Card 2 is "9", enter % fan KW (under "%") versus % max airflow (under "Hrs") in ascending order of airflow. Use profile no. 22 only.  
If col. 90, Card 5A is 7 or 8, enter % infiltration (under "%") versus ambient DBT (under "Hrs") in ascending order of DBT. First entry should be minimum % infiltration if using a key of 7. Use profile no. 21 only. Profiles 21 and 22 are limited to one line of data. Temp. entries must be greater than 0 degrees.

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7B-5

[illegible]

01-30-76

[illegible]

- 6 = 1 and 2 combined
- 7 = 1 and 4 combined (caution)
- 8 = 1 and 5 combined
- 9 = 1 and 2 and 5 combined
- (4) 0 = max O/A only
- 1 = max and min O/A
- 2 = supply air only
- 3 = max O/A, min O/A, supply air
- 4 = min O/A only

ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

WATER TREATMENT PLANT - 1000-4000-5000

NO PERM-75F-1AC-INFIL-FC FHE-1

MONTHLY AND ANNUAL LOADS

	HEATING HRS	HEAT 1000-HRS	COOLING 1000-HRS	COOL HOURS	HUMIDIFY HRS	IND PROC HRS	DIR PROC HRS	BS ELEC A KWH	BS ELEC B KWH	BS ELEC C KWH	TOT BS EL KWH	AUX F HRS
JAN	0.	0	745.	744	0.	0.	0.	0.	0.	298.	298.	0
FEB	0.	0	620.	672	0.	0.	0.	0.	0.	269.	269.	0
MAR	0.	0	675.	744	0.	0.	0.	0.	0.	298.	298.	0
APR	0.	0	723.	720	0.	0.	0.	0.	0.	288.	288.	0
MAY	0.	0	832.	744	0.	0.	0.	0.	0.	298.	298.	0
JUN	1.	1	845.	719	0.	0.	0.	0.	0.	288.	288.	0
JUL	0.	0	883.	744	0.	0.	0.	0.	0.	298.	298.	0
AUG	0.	0	935.	744	0.	0.	0.	0.	0.	298.	298.	0
SEP	0.	0	889.	720	0.	0.	0.	0.	0.	288.	288.	0
OCT	0.	0	1026.	744	0.	0.	0.	0.	0.	298.	298.	0
NOV	0.	0	998.	720	0.	0.	0.	0.	0.	288.	288.	0
DEC	0.	1	942.	744	0.	0.	0.	0.	0.	298.	298.	0
ANN	1.	1	10119.	8759	0.	0.	0.	0.	0.	3504.	3504.	0

# ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

NAVY MAINTURE STUDY 1958 AGANA GUAM NO PERM 10E JAC INFIL FC FRE-2

## MONTHLY AND ANNUAL LOADS

	HEATING MBTU	HEAT HOURS	COOLING TONS-HRS	COOL HOURS	HUMIDFCN MBTU	IND PROC MBTU	DIR PROC MBTU	BS ELEC A KWH	BS ELEC B KWH	BS ELEC C KWH	TOT BS EL KWH	AUX F MRS
JAN	0.	0	1195.	744	0.	0.	0.	0.	0.	298.	298.	0
FEB	0.	0	1031.	672	0.	0.	0.	0.	0.	269.	269.	0
MAR	0.	0	1118.	744	0.	0.	0.	0.	0.	298.	298.	0
APR	0.	0	1175.	720	0.	0.	0.	0.	0.	288.	288.	0
MAY	0.	0	1304.	744	0.	0.	0.	0.	0.	298.	298.	0
JUN	0.	0	1345.	720	0.	0.	0.	0.	0.	288.	288.	0
JUL	0.	0	1360.	744	0.	0.	0.	0.	0.	298.	298.	0
AUG	0.	0	1411.	744	0.	0.	0.	0.	0.	298.	298.	0
SEP	0.	0	1351.	720	0.	0.	0.	0.	0.	288.	288.	0
OCT	0.	0	1498.	744	0.	0.	0.	0.	0.	298.	298.	0
NOV	0.	0	1454.	720	0.	0.	0.	0.	0.	288.	288.	0
DEC	0.	0	1408.	744	0.	0.	0.	0.	0.	298.	298.	0
ANN	0.	0	15611.	8760	0.	0.	0.	0.	0.	3504.	3504.	0

# ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

NAVY NUISIURE STUDY 1958 AGAYA GUAM

NO PERM 80F JAC INFIL FC

FRF 3

## MONTHLY AND ANNUAL LOADS

	HEATING MBTU	HEAT HOURS	COOLING TON-HRS	COOL HOURS	MUNIDFCN MBTU	IND PROC MBTU	DIR PROC MBTU	BS ELEC A KWH	BS ELEC B KWH	BS ELEC C KWH	TOT BS EL KWH	AUX F HRS
JAN	55.	63	363.	681	0.	0.	0.	0.	0.	298.	298.	0
FEB	75.	89	293.	583	0.	0.	0.	0.	0.	269.	269.	0
MAR	51.	73	314.	671	0.	0.	0.	0.	0.	298.	298.	0
APR	17.	14	323.	706	0.	0.	0.	0.	0.	288.	288.	0
MAY	1.	13	385.	731	0.	0.	0.	0.	0.	298.	298.	0
JUN	21.	12	183.	708	0.	0.	0.	0.	0.	288.	288.	0
JUL	14.	16	391.	728	0.	0.	0.	0.	0.	298.	298.	0
AUG	11.	12	430.	732	0.	0.	0.	0.	0.	298.	298.	0
SEP	0.	9	308.	711	0.	0.	0.	0.	0.	288.	288.	0
OCT	6.	6	524.	738	0.	0.	0.	0.	0.	298.	298.	0
NOV	3.	5	517.	715	0.	0.	0.	0.	0.	288.	288.	0
DEC	21.	30	490.	714	0.	0.	0.	0.	0.	298.	298.	0
ANN	290.	342	4808.	8418	0.	0.	0.	0.	0.	3504.	3504.	0

# ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

NAVY MOISTURE STUDY 1958 AGANA GUAM NO PERM 75F 2AC INFIL FC ENE 4

## MONTHLY AND ANNUAL LOADS

	HEATING MBTU	HEAT HOURS	COOLING TON-HRS	COOL HOURS	HUMIDFCN MBTU	IND PROC MBTU	DIR PROC MBTU	BS ELEC A KWH	RS ELEC B KWH	BS ELEC C KWH	TOT BS EL KWH	AUX F MHS
JAN	0.	0	853.	744	0.	0.	0.	0.	0.	298.	298.	0
FEB	0.	0	717.	672	0.	0.	0.	0.	0.	269.	269.	0
MAR	0.	0	770.	744	0.	0.	0.	0.	0.	298.	298.	0
APR	0.	0	876.	720	0.	0.	0.	0.	0.	288.	288.	0
MAY	0.	0	1041.	744	0.	0.	0.	0.	0.	298.	298.	0
JUN	2.	2	1077.	718	0.	0.	0.	0.	0.	288.	288.	0
JUL	0.	1	1138.	744	0.	0.	0.	0.	0.	298.	298.	0
AUG	0.	0	1224.	744	0.	0.	0.	0.	0.	298.	298.	0
SEP	0.	0	1158.	720	0.	0.	0.	0.	0.	288.	288.	0
OCT	0.	0	1533.	744	0.	0.	0.	0.	0.	298.	298.	0
NOV	0.	0	1281.	720	0.	0.	0.	0.	0.	288.	288.	0
DEC	0.	0	1161.	744	0.	0.	0.	0.	0.	298.	298.	0
ANN	3.	3	12629.	8758	0.	0.	0.	0.	0.	3504.	3504.	0

## ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

NAVY WILSON STUDY 1958 AGANA GUAM NO PERM 75F JAC INFIL FC FRE 5

## MONTHLY AND ANNUAL LOADS

	HEATING BTU	HEAT HOURS	COOLING TON-HRS	COOL HOURS	NUMJFCN BTU	IND PROC BTU	DIR PROC BTU	BS ELEC A KWH	BS ELEC B KWH	BS ELEC C KWH	TOT BS EL KWH	AUX F HRS
JAN	0.	1	967.	743	0.	0.	0.	0.	0.	298.	298.	0
FEB	0.	0	814.	672	0.	0.	0.	0.	0.	269.	269.	0
MAR	0.	0	878.	744	0.	0.	0.	0.	0.	298.	298.	0
APR	0.	1	1039.	719	0.	0.	0.	0.	0.	288.	288.	0
MAY	0.	1	1256.	744	0.	0.	0.	0.	0.	298.	298.	0
JUN	5.	4	1309.	717	0.	0.	0.	0.	0.	288.	288.	0
JUL	1.	3	1391.	743	0.	0.	0.	0.	0.	298.	298.	0
AUG	0.	1	1510.	744	0.	0.	0.	0.	0.	298.	298.	0
SEP	2.	9	1420.	720	0.	0.	0.	0.	0.	288.	288.	0
OCT	4.	14	1632.	744	0.	0.	0.	0.	0.	298.	298.	0
NOV	4.	11	1555.	720	0.	0.	0.	0.	0.	268.	268.	0
DEC	0.	2	1377.	743	0.	0.	0.	0.	0.	298.	298.	0
ANN	17.	47	15149.	8753	0.	0.	0.	0.	0.	3504.	3504.	0

# ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

NAVY MISSILE STUDY 1958 AGANA GUAM LO PERM 75E 1AC INFIL +C FRE 6

## MONTHLY AND ANNUAL LOADS

	HEATING MBTU	HEAT HOURS	COOLING 100-HRS	COOL HOURS	HUMIDFCN MBTU	IND PROC MBTU	DIR PROC MBTU	BS ELEC A KWH	HS ELEC B KWH	BS ELEC C KWH	TOT BS EL KWH	AUX F HRS
JAN	0.	0	746.	744	0.	0.	0.	0.	0.	298.	298.	0
FEB	0.	0	628.	672	0.	0.	0.	0.	0.	269.	269.	0
MAR	0.	0	674.	744	0.	0.	0.	0.	0.	298.	298.	0
APR	0.	0	723.	720	0.	0.	0.	0.	0.	288.	288.	0
MAY	0.	0	833.	744	0.	0.	0.	0.	0.	298.	298.	0
JUN	1.	1	846.	719	0.	0.	0.	0.	0.	288.	288.	0
JUL	0.	0	884.	744	0.	0.	0.	0.	0.	298.	298.	0
AUG	0.	0	936.	744	0.	0.	0.	0.	0.	298.	298.	0
SEP	0.	0	890.	720	0.	0.	0.	0.	0.	288.	288.	0
OCT	0.	0	1027.	744	0.	0.	0.	0.	0.	298.	298.	0
NOV	0.	0	999.	720	0.	0.	0.	0.	0.	288.	288.	0
DEC	0.	0	943.	744	0.	0.	0.	0.	0.	298.	298.	0
ANN	1.	1	10128.	8759	0.	0.	0.	0.	0.	3504.	3504.	0

## PROCESS AND BASE ELEC LABELS

IND PROC =

DIR PROC =

BS ELEC A =

BS ELEC B =

BS ELEC C =

# ENERGY CONSUMPTION ESTIMATE PROGRAM FOR

MI PERM-75F-JAG-INTL-FC FWF 7

MONTHLY AND ANNUAL LOADS

HEATING	HEAT	COOLING	COOL	MULTIPLIER	IND PROC	DIR PROC	BS ELEC A	BS ELEC B	BS ELEC C	TOT BS EL	AUX F
KWH	HOURS	LOADS	HOURS	UNIT	UNIT	UNIT	KWH	KWH	KWH	KWH	HRS
JAN	0.	757.	744	0.	0.	0.	0.	0.	298.	298.	0
FEB	0.	656.	672	0.	0.	0.	0.	0.	269.	269.	0
MAR	0.	678.	744	0.	0.	0.	0.	0.	298.	298.	0
APR	0.	741.	720	0.	0.	0.	0.	0.	288.	288.	0
MAY	0.	864.	744	0.	0.	0.	0.	0.	298.	298.	0
JUN	0.	931.	744	0.	0.	0.	0.	0.	298.	298.	0
JUL	0.	931.	744	0.	0.	0.	0.	0.	298.	298.	0
AUG	0.	989.	744	0.	0.	0.	0.	0.	298.	298.	0
SEP	0.	942.	720	0.	0.	0.	0.	0.	288.	288.	0
OCT	0.	1086.	744	0.	0.	0.	0.	0.	298.	298.	0
NOV	0.	1055.	720	0.	0.	0.	0.	0.	288.	288.	0
DEC	0.	983.	744	0.	0.	0.	0.	0.	298.	298.	0
ANNUAL	1.	10549.	8759	0.	0.	0.	0.	0.	3504.	3504.	0

## PROCESS AND BASE ELFC LABELS

IND PROC =

DIR PROC =

BS ELEC A =

BS ELEC B =

BS ELEC C =

# ENERGY CONSUMPTION ESTIMATE PROGRAM FOR

NAVY AIRCRAFT STORE STUDY 1958-1959 AGANA GUAM HI PERM 705-340 INFIL FC FEE 8

MONTHLY ENERGY CONSUMPTION

MONTH	HEATING HRS	HEAT MBTU	COOLING HRS	COOL MBTU	HUMIDIFY HRS	IND PROC MBTU	DIM PROC MBTU	BS ELEC A KWH	BS ELEC B KWH	BS ELEC C KWH	TOT BS EL KWH	AUX F HRS
JAN	9.	28	1934.	744	0.	0.	0.	0.	0.	298.	298.	0
FEB	9.	10	1665.	672	0.	0.	0.	0.	0.	269.	269.	0
MAR	5.	12	1826.	744	0.	0.	0.	0.	0.	298.	298.	0
APR	4.	14	2019.	720	0.	0.	0.	0.	0.	288.	288.	0
MAY	5.	15	2284.	744	0.	0.	0.	0.	0.	298.	298.	0
JUN	9.	30	2312.	720	0.	0.	0.	0.	0.	288.	288.	0
JUL	17.	30	2427.	744	0.	0.	0.	0.	0.	298.	298.	0
AUG	7.	20	2534.	744	0.	0.	0.	0.	0.	298.	298.	0
SEP	4.	15	2413.	720	0.	0.	0.	0.	0.	288.	288.	0
OCT	5.	9	2613.	744	0.	0.	0.	0.	0.	298.	298.	0
NOV	1.	15	2510.	720	0.	0.	0.	0.	0.	288.	288.	0
DEC	4.	15	2340.	744	0.	0.	0.	0.	0.	298.	298.	0
ANN	60.	223	26908.	8760	0.	0.	0.	0.	0.	3504.	3504.	0

PROCESS AND BASE FEEC LABELS

IND PROC =

DIM PROC =

BS ELEC A =

BS ELEC B =

BS ELEC C =

# ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

NAVY HUISTURE STUDY 1958 AGANA GUAM NO PERM 75F 1AC INFIL VAV RH ERE 9A 30%

## MONTHLY AND ANNUAL LOADS

	HEATING BTU	HEAT HOURS	COOLING TON-HRS	COOL HOURS	HUMIDIFYN MBTU	IND PRUC MBTU	DIM PRUC MBTU	RS ELFC A KWH	BS ELEC B KWH	BS ELEC C KWH	TOT RS EL KWH	AUX F PRS
JAN	2502.	507	1247.	744	0.	0.	0.	0.	0.	24.	24.	0
FEB	2416.	477	1094.	672	0.	0.	0.	0.	0.	19.	19.	0
MAR	2461.	568	1143.	744	0.	0.	0.	0.	0.	19.	19.	0
APR	2569.	622	1227.	720	0.	0.	0.	0.	0.	17.	17.	0
MAY	2138.	617	1330.	744	0.	0.	0.	0.	0.	18.	18.	0
JUN	2126.	563	1142.	720	0.	0.	0.	0.	0.	18.	18.	0
JUL	2255.	596	1407.	744	0.	0.	0.	0.	0.	18.	18.	0
AUG	2043.	588	1436.	744	0.	0.	0.	0.	0.	19.	19.	0
SEP	2176.	557	1398.	720	0.	0.	0.	0.	0.	19.	19.	0
OCT	1823.	488	1495.	744	0.	0.	0.	0.	0.	25.	25.	0
NOV	1719.	454	1445.	720	0.	0.	0.	0.	0.	26.	26.	0
DEC	2116.	469	1426.	744	0.	0.	0.	0.	0.	29.	29.	0
ANN	26345.	6506	16029.	8760	0.	0.	0.	0.	0.	251.	251.	0

-----AIRTEL----- STUY-195A-46ACA-GIAM -----10U PERH-75A-IAC-INFTL VAV KH ENE 9B 15%

14U PERM 754-1AC-INTEL VAV RH EHE 9B 15%

# CONTRAST AND ANOMALY PAIRS

MONTH	HEATING KWH	STEAM KWH	COOLING TONS	CAPL HOURS	MANUFACT KWH	IND PROD KWH	DIR PROD KWH	HS ELEC A KWH	BS ELEC B KWH	AUX F KWH	TOT BS EL KWH
JAN	469.	291	1050.	744	0.	0.	0.	0.	0.	15.	0
FEB	515.	285	910.	672	0.	0.	0.	0.	0.	11.	0
MAR	521.	286	976.	744	0.	0.	0.	0.	0.	10.	0
APR	294.	239	1028.	720	0.	0.	0.	0.	0.	8.	0
MAY	204.	204	1105.	744	0.	0.	0.	0.	0.	10.	0
JUN	241.	211	1162.	720	0.	0.	0.	0.	0.	10.	0
JUL	251.	229	1216.	744	0.	0.	0.	0.	0.	10.	0
AUG	192.	185	1259.	744	0.	0.	0.	0.	0.	11.	0
SEP	221.	217	1211.	720	0.	0.	0.	0.	0.	10.	0
OCT	134.	165	1333.	744	0.	0.	0.	0.	0.	17.	0
NOV	150.	144	1292.	720	0.	0.	0.	0.	0.	19.	0
DEC	515.	239	1252.	744	0.	0.	0.	0.	0.	22.	0
TOTAL	5087.	2701	13030.	8760	0.	0.	0.	0.	0.	154.	0

## CHAPTER 8

### PAINTS, COATINGS AND ROOFING

#### Purpose

This Chapter discusses field observations, design criteria and conclusions regarding paints, coatings and roofing on buildings in humid climates.

#### Field Observations

Our trip to the Naval Facilities Engineering Command Pacific Division started October 27, 1976. We were briefed by Admiral John Fisher, the then Commander, and departed in company with one of his Mechanical Engineers, Mr. Hiroshi Kojima.

Proceeding on to Guam, we examined Buildings 1300 and 1301 at the Naval Air Station at Agana. The problems of the air conditioning systems are covered in other Chapters of this report. The roofs of these buildings, as well as Buildings 294, 295, and 296, were reasonably done with a major error being committed in that an effort was made to save approximately 4' of insulation around the perimeters. These perimeters are extensions of the roof deck to act as canopies and rain shields for the deck below. The insulation was provided only over the air conditioned space and the transition from an insulated membrane to a non-insulated membrane was done without the use of cant strips. A built-up roof will not do this and remain tight. This technique entraps air and moisture and the sun generates blisters and splits.

The appearance of both interior and exterior paint can only be described as bad. It is obvious that no thought was given to

the choice of the class of paint in relationship to the potential dampness of the receiving surface. Enamels were used where breathing paint should have been used and vice versa. It was also obvious that many of the substrates which had received paint were wet at the time they were painted. Mold and mildew were evident everywhere. The most offensive, however, was the odor.

We observed two pieces of concrete under the same exposure about 5' apart. One that was painted had all the typical paint problem of non-adhesion, blistering, mildew growth, cracking and spalling. The other had a cement fill coat with a white Medusa cement wash. This cement wash had none of the typical paint problems, no mold growth and no water staining. The coating was shedding exterior water and was allowing the passage of interior moisture.

Guam, as well as the Philippines, is in a typhoon wind rated area. The detailing of all the roofs observed indicates that proper windproofing is not being accomplished either by design, workmanship, or by lack of inspection. Most of the observed roofs are highly vulnerable to wind blow-off.

One roof observed during the visit to Cubi Point Naval Air Station had a perimeter gravel stop and fascia of copper secured directly to the concrete deck with galvanized nails or 1/8" galvanized bolts. The galvanic action between dissimilar material was consuming the bolts, nails, and copper itself.

Local engineers informed us that very little wood is used in and around roof construction in an effort to reduce termite activity. Properly treated wood, which may have to be imported, is avail-

able; however, its inclusion would greatly reduce the potential of wind blow-off.

Major mold growth was occurring in the protected doorways of all typical BOQs and BEQs. The designers provided these doorways with masonry "eyebrow" effects for rain and sun protection. Due to lack of sunlight and air movement, the mold growth in these areas is excessive.

Mold and paint failure is very obvious on the outer edges of the exposed concrete walkways of practically all BEQs and BOQs. These walkways are a structural slab extension and, therefore, they act as a cold radiator and when painted, the paint automatically fails.

In one unit headquarters building in Guam, we observed a service man grinding down spalled, blistered paint with a power grinder to prepare the surface for new paint. The area that he had just completed and the area ahead of him was full of blisters approximately 3/8" to 1/2" in diameter which were raised from the substrate approximately 1/4". In puncturing these blisters with a penknife from below, darkish brown liquid drained from them and ran down the wall. This was mold and fungus feeding upon the coating. The service man had absolutely no protection to protect himself from the ingress of mold and fungus into his eyes, his ears, his lungs, etc. Other service men in the same general area were being subjected to the same ingress. No effort had been made to sterilize and prekill existing mold and fungus before demolition of the spalled paint.

It was interesting to note both in Guam and the Philippines the use of roof mounted equipment. In all cases, the equipment was poorly flashed, and its very presence makes it susceptible to wind damage. Some buildings in the vicinity of trees had clogged drains, gutters, eave boxes, etc. Apparently no attempt to regularly clean these water reliefs is being made.

In July 1977, we visited the Naval Magazine in Charleston, particularly Building 458 in Area 108. This building is poured concrete up to about 10' high and then extends another 50' to 60' using transite cladding. The occupancy of the building requires that there be three subterranean levels. Strangely enough, the third or lowest level showed no water seepage from the exterior while the first and second levels had wet walls and water on the floors. Obviously the exterior below grade waterproofing was either incorrectly designed, provided or had failed for other reasons. The lap seams of the transite cladding contained no neoprene stripping or additional caulking and these walls were leaking badly in the higher sections due to the influence of wind driven rain. Leaks were coming in around the blowout hatches in the roof due to obvious poor flashing. Otherwise, the 5-ply slag surface roof was in good shape after approximately seven years.

A BEQ of the Welton Becket design was examined at the Charleston Navy Hospital. The exterior stucco was color tinted. The quality control of the color batches was poor and each new batch was obvious even to an untrained eye. There was no sign of mold or mildew on the stucco. Examination of the roof indicated that it

had been provided in good practice. However, the associated metal work, i.e. gutters, eave boxes, etc. was poorly done. The joints of the gutters were leaking and the water was staining the walls. Exterior metal that had been painted was painted over an unprimed surface, and therefore, was spalling badly.

In New Orleans we visited the Naval Weapons Support Activity of the 8th Naval District. We were asked, while there, to examine the meat preparation room of the base commissary as a courtesy. Suggestions to this problem were given to the local engineers for correction.

Building 703 was examined. The walls are of brick and white stucco. No exterior paint had been provided on the walls, and therefore, no problem existed. Examination of the roof showed 40 to 50 blisters, which is a workmanship error, but correctable. The roof of the Mess Hall of this complex is a classic example of asphalt slippage due to the improper use of a low melt point mopping asphalt.

Efflorescence showed on the south wall of Building 703 and also on the west wall of the new, but yet unoccupied BEQ No. 711. At the time of our visit, Building 710 and 711 had not been accepted. The roofs of these buildings, viewed from the roof of 703, would indicate that there was insufficient aggregate and lack of embedment of the surfacing aggregates. Local engineers are urged to carefully inspect and require corrections before acceptance.

We also visited the local BOQ and concentrated particularly on

the dining room and kitchen areas. The perimeter flashings and gutter details were poorly designed. The one interior drain provided, once clogged, will put water under all of the counter-flashings. The counterflashings originally designed were not inserted into reglets or under a coping but were secured atop the coping and depend solely on caulking for watertightness. A blister full of water was found in the center of the roof at the mouth of the air conditioner condensate pipe. The general brick work seemed to be well done. However, the mortar was porous and soft.

At Pensacola Naval Air Station, we examined Building 2348. This building had recently been reroofed with a superimposed system of approximately 3/4" of fiberglass insulation and one ply of 90 lb. mineral surface 19" selvage edge in a white color. No new or superimposed metal edging had been provided. Walking the roof, it was obvious that the newly provided fiberglass insulation was not adhered to the original roof, but was very loose. This roof is highly susceptible to wind blow-off and without the required edge protection, it is a reasonable assumption that the next hurricane will take it away.

Additional buildings such as No. 3468 and No. 3470 were examined. The roofs, paints and coatings were acceptable.

#### Design Publications and Reports Reviewed

1. NAVFAC M0-110, Paints and Protective Coatings
2. NAVFAC - Section 07000, Guide Specification - Built-Up Bituminous Roofing
3. NAVFAC - Specification TS-09910 (July 1972) - Section 9 Painting of Buildings (Field Painting)

4. NAVFAC - Specification 09910 (October 1976)
5. NAVFAC - Specification TS-05320 (October 1974), Steel Roof Decking
6. NAVFAC - Specification Section 07241 (April 1976) Roof Insulation
7. NAVFAC - Specification TS-07520 (July 1974), Prepared Roll Roofing
8. Army - TM5-809-8 (July 1974), Metal Roofing and Siding
9. Army - TM5-805-14 (March 1966), Roof Design
10. Cubi Point, PI - (June 1974), Painting Contract for New BEQ and BEQ Modified
11. Navy - Finegayan, Guam - Section 9, Field Painting BEQ Modified NAS
12. Navy - Agana, Guam - Section 9B, BEQ Modified NAS
13. Navy - Air Conditioning Fix Project - Section 9B, Field Painting BOQ and BEQ, Cubi Point, PI
14. Navy - Original Contract - Section 9C, Field Painting BOQ - Cubi Point, PI
15. Navy Memorandum - May 1974, NAVFAC San Francisco to Hawaii and reply.

#### Notes on Design Publications

1. NAVFAC MO-110
  - A. Section 2, paragraph 1.2.1 "Typical causes of failure are sunlight, temperature variations, fresh and salt water, water vapor, rot, mildew, chemicals and abrasions."
  - B. Paragraph 1.4.4.3 "The most difficult environments to which structures are exposed . . .  
 "C" intensive ultraviolet radiation as present in the southeast United States.  
 "D" excessive moisture (continual high humidity and/or heavy rainfall) as present in the southeastern U.S. and the tropics."  
  
 "There must be no compromise whatsoever in the paints used, painting operations, and inspections, in order to achieve the desired surface in abnormal environments.
  - C. Chapter 3 - Safety - Paragraph 3.1.2.3 "Respiratory protection personnel must wear proper type of face mask in hazardous areas. All devices must be approved by the U.S. Bureau of Mines."

- D. Chapter 4 - Paragraph 4.4.2.2 "Power tool cleaning is to be preceded by solvent or chemical treatment.
  - E. Chapter 5 - Paragraph 5.2.3.1  
 "B" Mildew (fungii): Paint coatings exposed in humid climates or in warm damp rooms, e.g. shower rooms, may be attacked by fungii which feed on the coating. Mildew will grow and become quite unsightly and will accelerate degradation of the coating . . . the presence of mildew can be determined by using household bleach . . . use specially formulated - moisture - resistant and mildew-resistant paints for these exposures.
  - F. Chapter 8 - Paragraph 8.4.1.4  
 "If blistering and peeling cannot be eliminated from porous materials . . . paint the outside surface with breathing type paints such as latex or cement paints."
  - G. Chapter 10 - Paragraph 10.2.2.7 "In applications where mildew is a problem . . . it can be reduced and even eliminated either by the proper choice of paint or the addition of a mildewcide (fungicide) to the paint.
2. NAVFAC - Section 07000  
Guide Specification - Built-Up Bituminous Roofing  
 Notes to specifier. Paragraph 8 "Double surfacing shall be used where one or more of the following conditions exist:  
 "B" In tropical and semi-tropical areas where roofs are exposed to intense solar radiation.  
 "D" "In high wind areas (70 mph and over) to insure against damage from wind-blown aggregate." No reference can be found in this guide specification for careful care being required in the attachment of the insulation, the membrane, edge detail, or wood nailers to the deck in exceptionally high wind areas such as hurricanes and typhoons.
  3. NAVFAC - Specifications TS-09910  
Painting of Buildings (Field Painting)  
 "A" Paragraph 6.2 carefully follows procedures outlined in MO-110 for preparation of concrete and masonry surfaces. Note in same paragraph says "concrete should, if possible, be aged at least one year prior to painting."  
  
 Paragraph 6.4 "new plaster must be aged a minimum of two weeks prior to application of the first coat of latex paint; first coat must age for a minimum of one month before application of second coat.  
  
 Paragraph 8.1.1 permits exterior lead-free oil paint TT-P-105, exterior alkyd oil MIL-P-52324, exterior acrylic emulsion paint TT-P-19 or exterior alkyd trim TT-P-37 or oil paint TT-P-81.  
  
 Paragraph 8.3.2 permits cement emulsion fill coat and cover coat of exterior emulsion paint on exposed concrete masonry unit surface. Formula for fill coat follows.

5. NAVFAC - Specification TS-05320  
Steel Roof Decking  
Paragraph 5.2 - Note: Specify 1.25 commercial coating when severe corrosive conditions are present.
6. NAVFAC - Specification Section 07241  
Roof Insulation  
Paragraph 6.1 "Each layer shall be firmly embedded in a solid steep asphalt mopping."  
  
Paragraph 6.9.1 "Roof insulation shall be mechanically fastened to roof decks in addition to mopping with mechanical fasteners or clips for a 4 ft. wide strip around the perimeter of the roof, regardless of the roof slope."
9. Army - TM5-805-14  
Roof Design  
Paragraph 1C(2) "In tropical areas such as Puerto Rico and Okinawa monolithic - concrete structural roof decks provide satisfactory waterproofing without application of roofing."  
  
Paragraph 8D "The National Bureau of Standards study performance of roofing on Guam, and Okinawa and earlier studies of roofing in Puerto Rico have indicated that the most effective treatment of joints in bare monolithic-concrete decks must contain a reinforcing fabric strip etc., etc."
10. Cubi Point, PI  
Painting Contract for New BEQ and BEQ Modified  
Paragraph 9E.6.7 "Do not apply paint or sealer on plaster when its moisture content exceeds 8% as determined by a testing device . . . "  
  
Paragraph 9E.7.1 "Do not apply exterior paint during fog or rainy weather or until surfaces have been dried from the effects of such weather . . . "  
  
Note: TT-P-29 is not even mentioned for interior use. TT-P-19 is only listed under Federal Specifications section and not specified.
11. Navy - Finegayan, Guam  
Field Painting BEQ Modified NAS  
TT-P-19 or TT-P-29 are not specified or required.
12. Navy - Agana, Guam  
BEQ Modified NAS  
Paragraph 9B.5.5 "All exterior concrete masonry unit surfaces shall be dampened with a soak spray immediately before the coating is applied - requires application of cement-emulsion fill coat.  
  
Paragraph 9B.5.7.1 requires two coats of TT-P-19 over cement emulsion coat.

Paragraph 9B.5.7.6 interior concrete masonry units require TT-P-95 with finish coat of TT-P-51. TT-P-29 not mentioned.

13. TT-P-19B(1) is listed under Federal Specifications but otherwise is unspecified. TT-P-29 is not even listed.
14. TT-P-19B(1) is listed under Federal Specifications but otherwise is unspecified. TT-P-29 is not even listed.
15. Memorandum describes a paint failure at NCS Finegayan wherein remedial paint combination was a prime coat of TT-S-179; undercoat: TT-E-543; finish coat TT-E508. The remedial paint program failed in thirteen months. Third attempt at solution was the recommendation of TT-P-29 as a sealer and two finish coats of TT-P-29.

#### Discussion

On returning from the Far East trip, a meeting was held at NAFAC Headquarters in Alexandria with Mr. Ernest Violet, Mechanical Section (now retired); Dr. Harold Lasser, Technology Support Branch (now retired); Mr. Robert Page, Microbiology Division (now retired); Mr. Ben Johnson, Mechanical Section, South Carolina; and Mr. Robert Moore of ARMM Consultants.

An extensive report was made by Mr. Moore to these gentlemen on the failure of the paints and coatings in the Pacific and the general approach of surface preparation when getting ready to re-paint.

Dr. Lasser, who was the author of MO-110, stated unequivocally "Only three paints are acceptable in the tropics: TT-P-29, interior; TT-P-19, exterior; TT-P-21, unpainted masonry surface."

Mr. Robert Page described the mold and fungus and said that the only adequate protection for a service man preparing mold and fungus infected substrates was an air supplied protective suit (Figure 10, page 3-6, MO-110).

Dr. Lasser referred to work being done at the National Bureau of Standards by Dr. Paul Campbell and Ms. Mildred Post. A subsequent conversation with Ms. Post revealed approximately 4 or 5 recommended paint removers. All these paint removers ultimately require cleaning with high pressure water hose. In confined areas or viable spaces, this is unacceptable. The most important input was that all existing fungus and mold filled blisters must be carefully broken and the surface cleaned with clorox and a detergent without phosphate to prekill the mold before making any substrate repair prior to repainting. This entire subject of original painting, repainting, and medical protection of personnel should be done by a proper in-house task force. The subject is serious medically and existing paint selections for both new construction and repair work, their application and performance, has been super-expensive and has failed.

A laboratory analysis of samples returned from Guam and the Philippines is included as an example on pages 8A-1 to 8A-8.

#### Conclusions and Recommendations

1. Paints and coatings have failed in tropical climates because:
  - a. The wrong paints were specified. No psychrometric consideration given in the selection of classes of paints and where they were to be provided.
  - b. No thought was given to the concept of the incompatibility of basic coatings.
  - c. Application of paints and coatings requiring dry substrates were made over wet surfaces.
  - d. Painting over fungus and mildew was accomplished with poor surface preparation.

- e. There was improper mixing of paint batches.
  - f. The lack of knowledge of mold and fungus on building materials.
2. Acceptable paints for air conditioned buildings in humid climates are:
- TT-P-29 interior
  - TT-P-19 exterior
  - TT-P-21 unpainted masonry
3. It is recommended that you form an in-house task force to provide education quickly on paint selections and medical protection for service men and outside contractors repainting substrates.
4. Roof designs and provisions in Guam and the Philippines are of a higher level of performance than in the domestic United States.
5. Windproofing requirements of roofs, both domestic and in the Pacific, must be rapidly upgraded to prevent major premature losses.

The revisit in August, 1978 changed none of the above original recommendations with the exception of #2.

On the revisit, we had the opportunity to examine an office-warehouse facility on Guam that had been experimentally coated with a textured coating, manufactured by Textured Coatings of America, Los Angeles, California, in 1974. After four years, the coating showed no blisters, peeling, blemishes, etc. on the face, and had bonded satisfactorily to masonry, wood, steel, aluminum, etc.

The technique adopted for that building and for succeeding build-

ings was to completely blast all surfaces with a high pressure water jet. The water jets had been borrowed from the Guam Ship Repair Facility. The blasting removed most of the original coatings, imperfections in the masonry, and all mold and mildew, leaving a clean, acceptable surface which was ready for painting after drying for three to four days.

We observed the water jet in action, at the Naval Communications Center in Guam and inspected installations of the textured coating both inside and outside in several buildings. The textured coating is available in Piolite or in a plasticized vinyl Toluene acrylic resin type.

Using the low perm rated type on the exterior, it would appear that this is a very successful application of textured coating, in that the material is providing a reasonably acceptable vapor retarder on the exterior of the building.

The program was instituted on Guam by a Mr. Ahlberg. Mr. Ahlberg is now stationed in Subic Bay where we had an opportunity to discuss his program at length. Officials at Port Hueneme had provided the Command with names of various manufacturers of textured coatings in order to be non-proprietary.

It is the further recommendation of this report that the water blast - textured coating operation continue under careful observation.

The August 1978 trip showed an experimental use of an adhered elastomeric roofing system. In general, the fields of the roofs were well done and the system was performing well. There

was a general lack of attention to details such as areas at the perimeters, vents, stacks, flashing, etc. This deficiency can be overcome easily with careful inspection and education of the roofing mechanics.

Two such roofs had survived a typhoon. The composition of the material is light and heat reflecting, as well as having an anticipated thirty year life expectancy. The system is acceptable for use in humid climates.

Ad-A064 768

ARM CONSULTANTS INC GLOUCESTER NJ  
MOISTURE PROBLEMS IN BUILDINGS.(U)  
DEC 78 R J MOORE, L G SPIELVOGEL

F/G 13/8

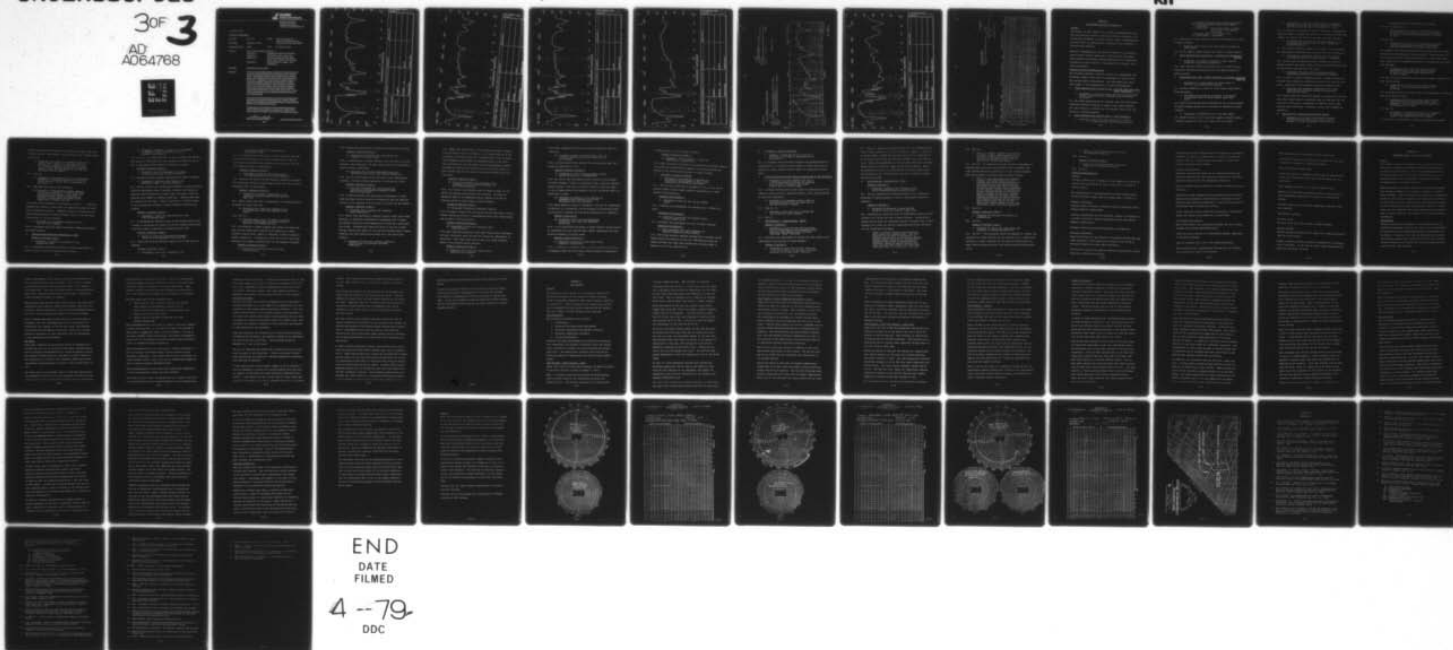
N62467-76-C-0696

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DDC

**Sadtler****Research Laboratories, Inc.**  
Subsidiary of Block Engineering, Inc.3316 Spring Garden Street  
Philadelphia, Pa. 19104  
Telephone: (215) 382-7800  
TWX 710-670-1186 Cable SADTLABS

November 22, 1976

REPORT OF ANALYSIS

SAMPLES: Four (4) FROM: Armm Consultants, Inc.  
North King and Warren Streets  
RECEIVED: November 15, 1976 Gloucester City, New Jersey 08030  
LABORATORY NO: 81323 ATTN: Mr. Robert J. Moore  
SUBJECT: Four (4) paint samples identified as:  
Sample No. 1 Building 8316, Cubi Point, Philippines  
Sample No. 2 CPO Quarters - NAS - Agana, Guam  
Sample No. 3 Building B-1-130 Annex, NAS, Agana,  
Guam. Interior corridor wall, warm side.  
Sample No. 4 Building 133-NCS - Finnegan - Guam.  
Corridor area.

REQUEST: Identification of resin systems

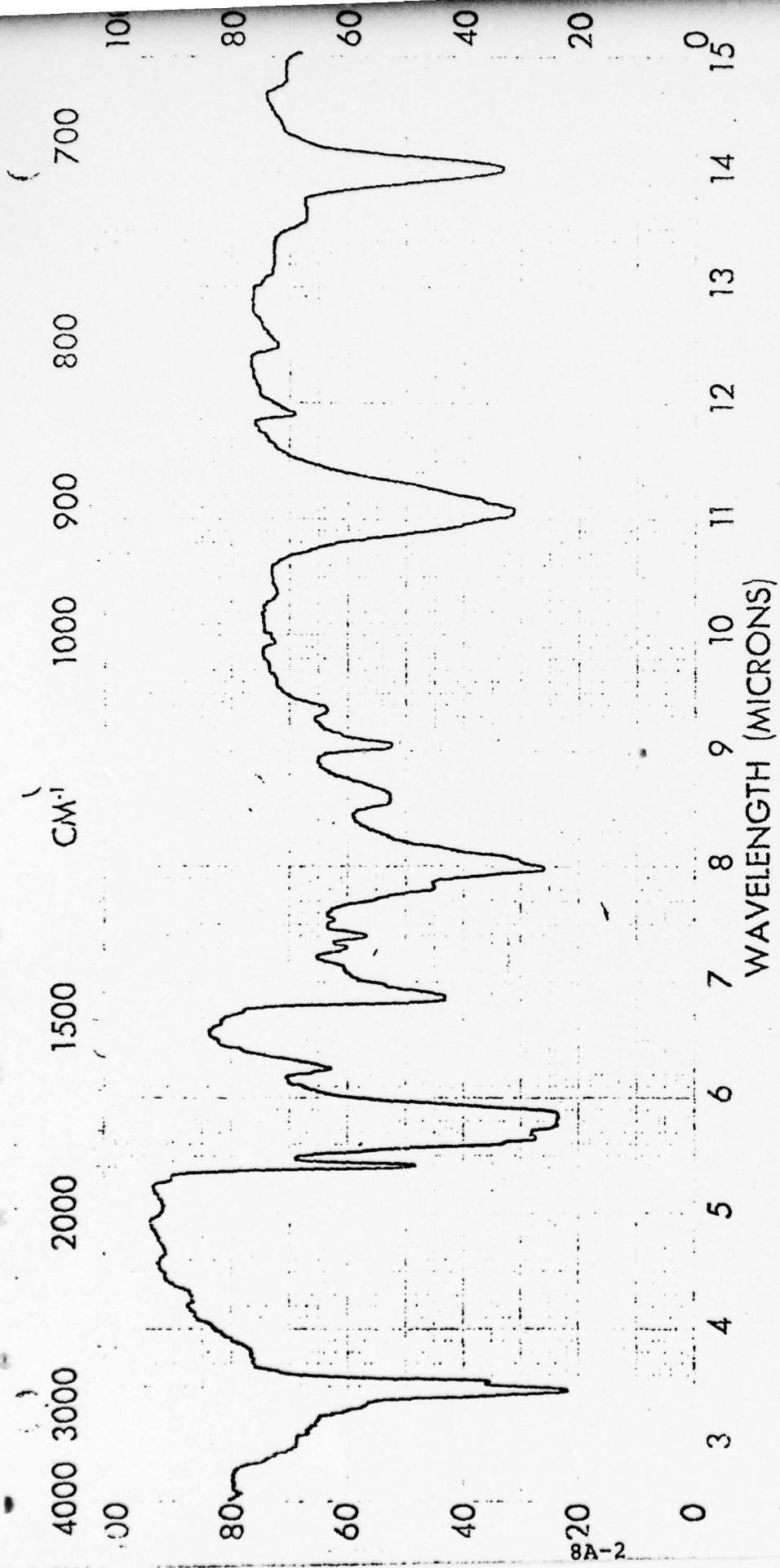
RESULTS: Portions of the submitted samples, as received, were pyrolyzed in small test tubes and the pyrolysis products condensed on sodium chloride plates. The infrared spectrogram of the pyrolyzate was run between sodium chloride plates on a Perkin-Elmer Model 137 infrared spectrophotometer. The absorption measurements of samples numbers 1, 2, 3 and 4 are recorded on spectrograms numbers 81323-1, 81323-2, 81323-3 and 81323-4 respectively. Direct comparison of spectrum number 1 with those of the Sadtler Reference Spectra Collections (Pyrolyzates volumes) showed a perfect match with the reference curve of Setal 62 commodity, a long soyabean oil alkyd resin. A copy of the reference spectrum of this substance (D 8745) is enclosed for comparative purposes.

Absorption features between spectra numbers 2 and 3 are identical and characteristic of styrene alkyd copolymer resin. A typical reference spectrum of this substance, Cycopol S102-5 (spectrum number 81323-R prepared in our laboratories) is enclosed.

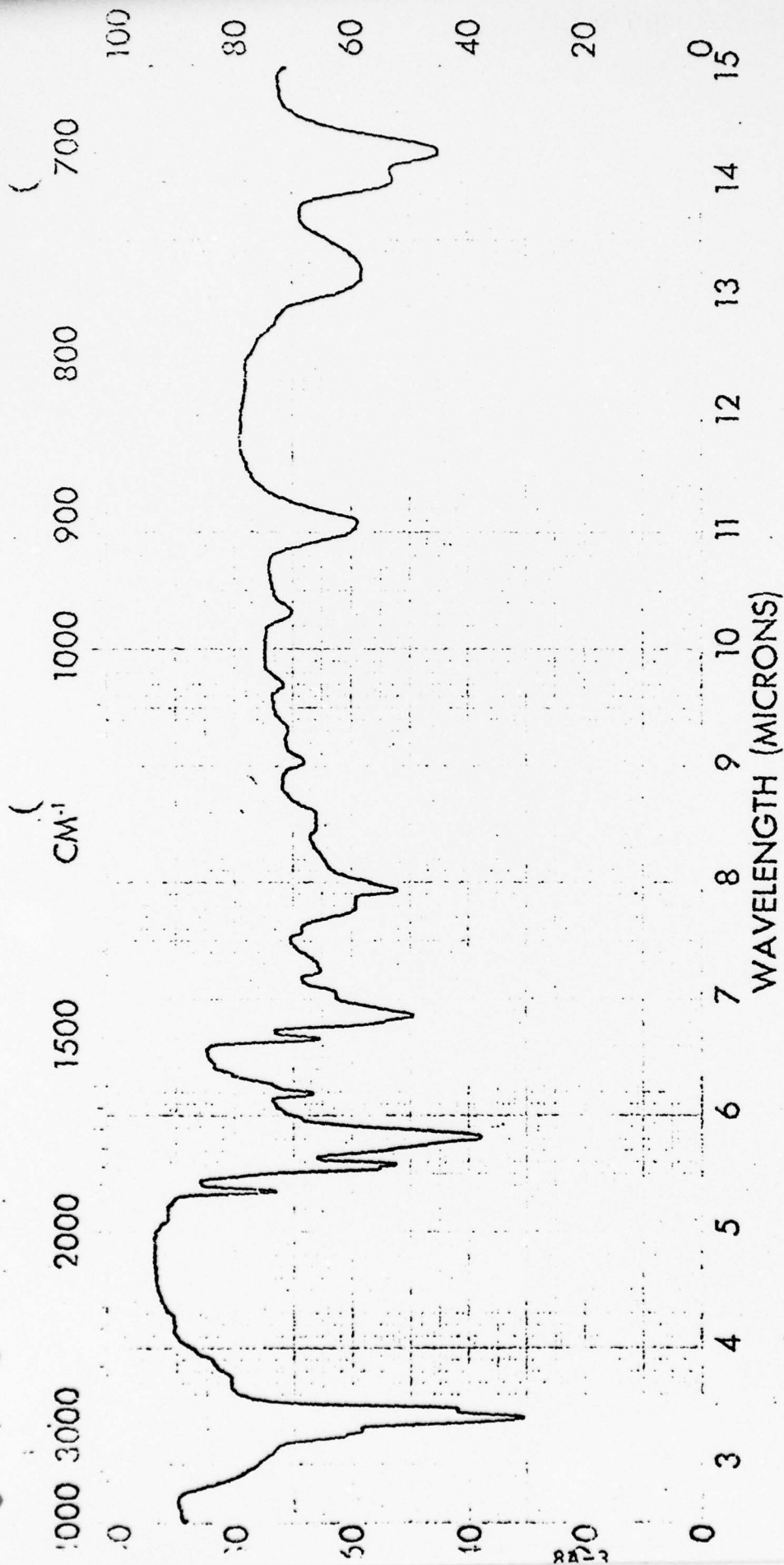
The absorption curve of spectrum number 4 showed good agreement with the reference curve of BA-12, an acrylic resin. A copy of the reference spectrum (D 8420) is also enclosed for comparative purposes.

*William Shick*  
William Shick, Research Chemist

SERVING SCIENCE SINCE 1874

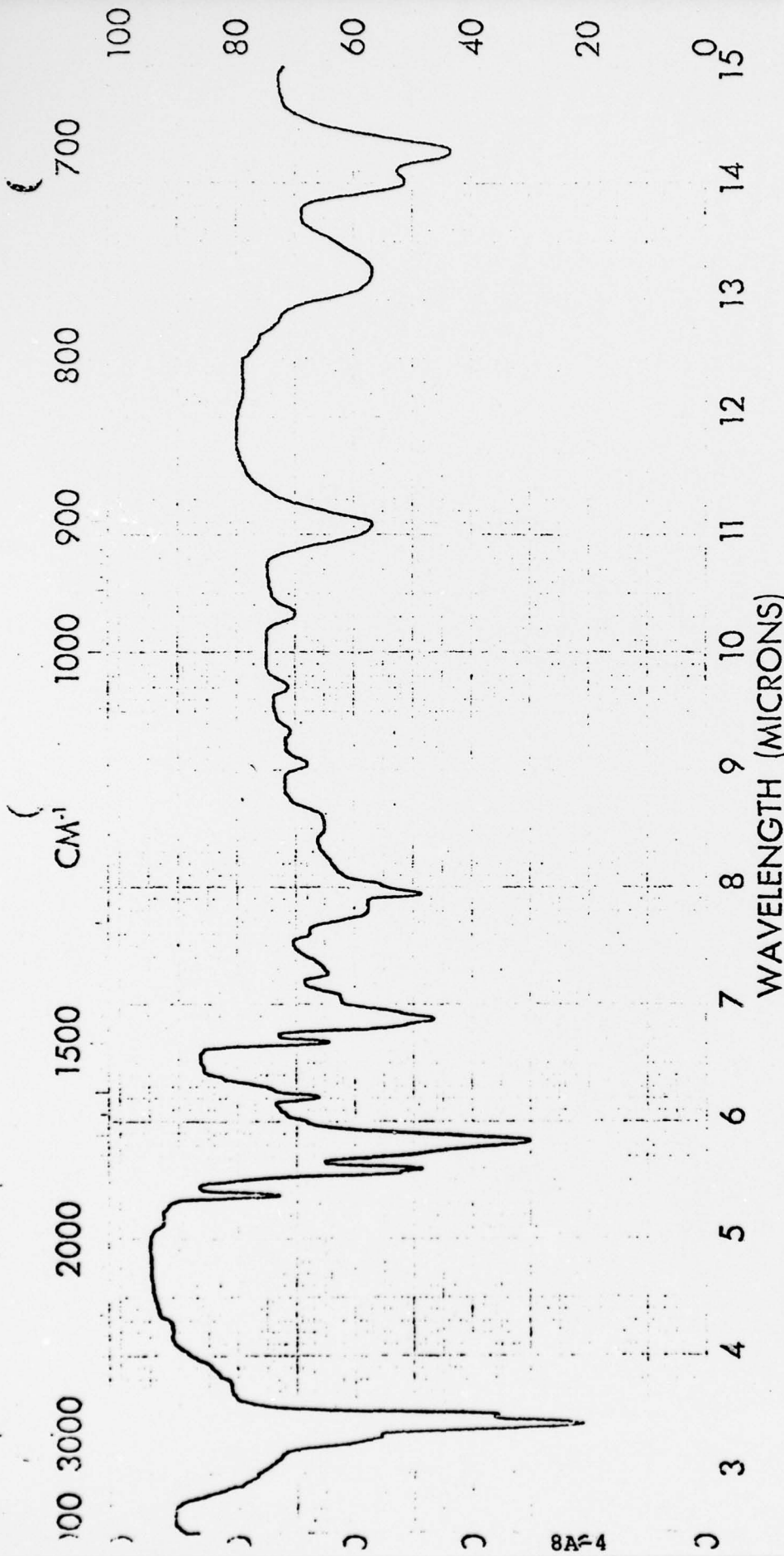


SPECTRUM NO. <u>81323-1</u>		ORIGIN <u>Armm Consultants, Inc.</u>		LEGEND		REMARKS	
SAMPLE <u>No. 1, Building 8316</u>				1.			
<u>Cubi Point, Philippines</u>		PURITY		2.			
		PHASE <u>B.S.</u>		DATE			
		THICKNESS		OPERATOR			



SPECTRUM NO. \_\_\_\_\_  
SAMPLE \_\_\_\_\_

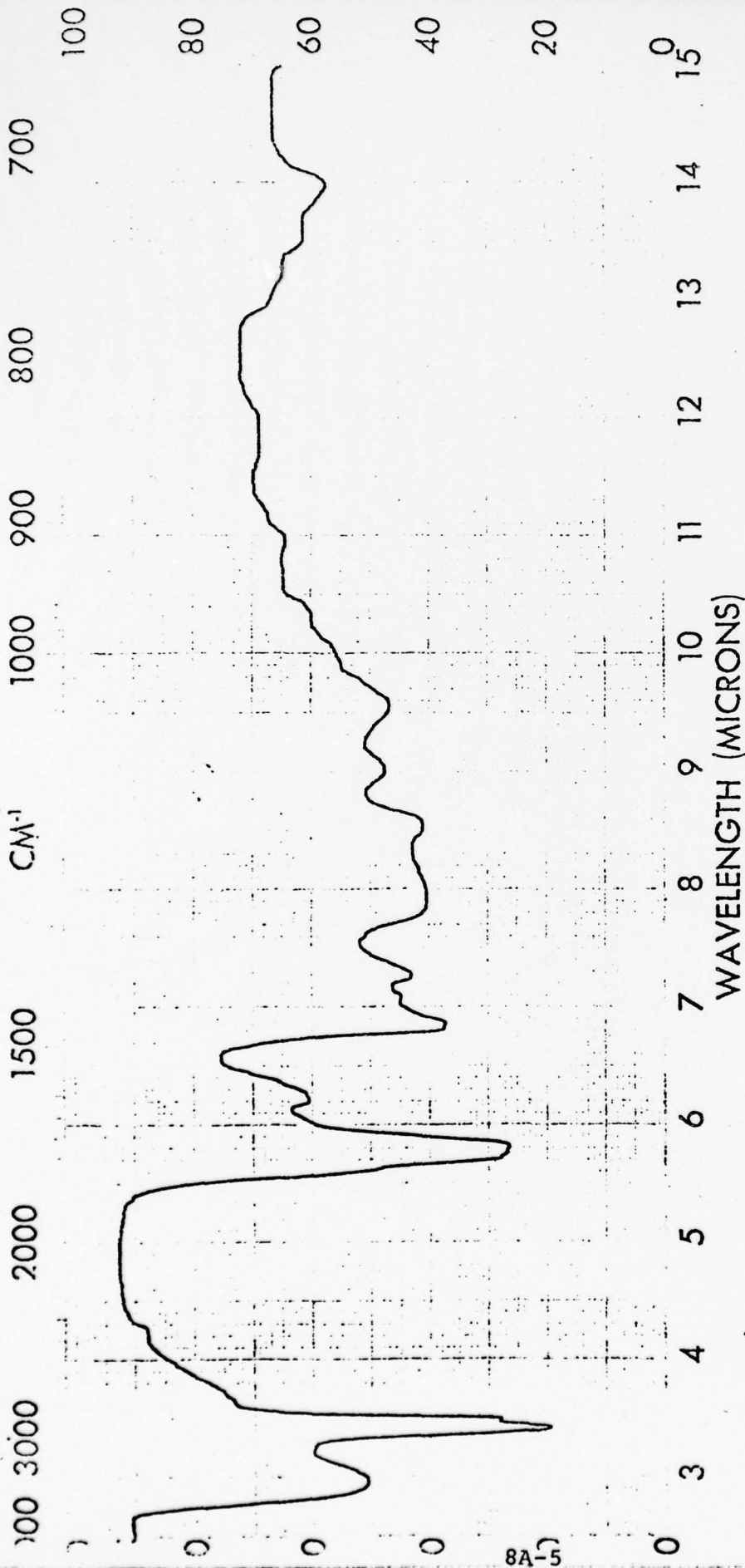
SPECTRUM NO. 81323-2	ORIGIN Arm Consultants, Inc	LEGEND	REMARKS
SAMPLE No. 2, CPO Quarters		1.	
NAS - Agana, Guam		2.	
	PURITY	DATE	
	PHASE B.S.		
	THICKNESS	OPERATOR	



8A-4

SPECTRUM NO. <u>81323-3</u>		ORIGIN <u>Armin Consultants, Inc</u>		LEGEND _____		REMARKS _____	
SAMPLE <u>No. 3, Bldg. 13-1-130</u>		PURITY _____		1. _____		_____	
<u>Annex, NAS, Agana, Guam</u>		PHASE _____		2. _____		_____	
_____		THICKNESS _____		DATE _____		_____	
_____		_____		OPERATOR _____		_____	

SPECTRUM NO. \_\_\_\_\_  
SAMPLE \_\_\_\_\_



8A-5

SPECTRUM NO. <u>81323-4</u>		ORIGIN <u>Armin Consultants, Inc.</u>		LEGEND		REMARKS	
SAMPLE No. <u>4, Bldg. 133-</u>				1.			
NCS - Finnegan, Guam				2.			
		PURITY		DATE			
		PHASE <u>B.S.</u>		OPERATOR			
		THICKNESS					

SPECTRUM NO. \_\_\_\_\_  
SAMPLE \_\_\_\_\_



SETAL 62

LONG SOYABEAN OIL ALKYD RESIN

COMMERCIAL - PREPARED

1968

A. V. 4-10

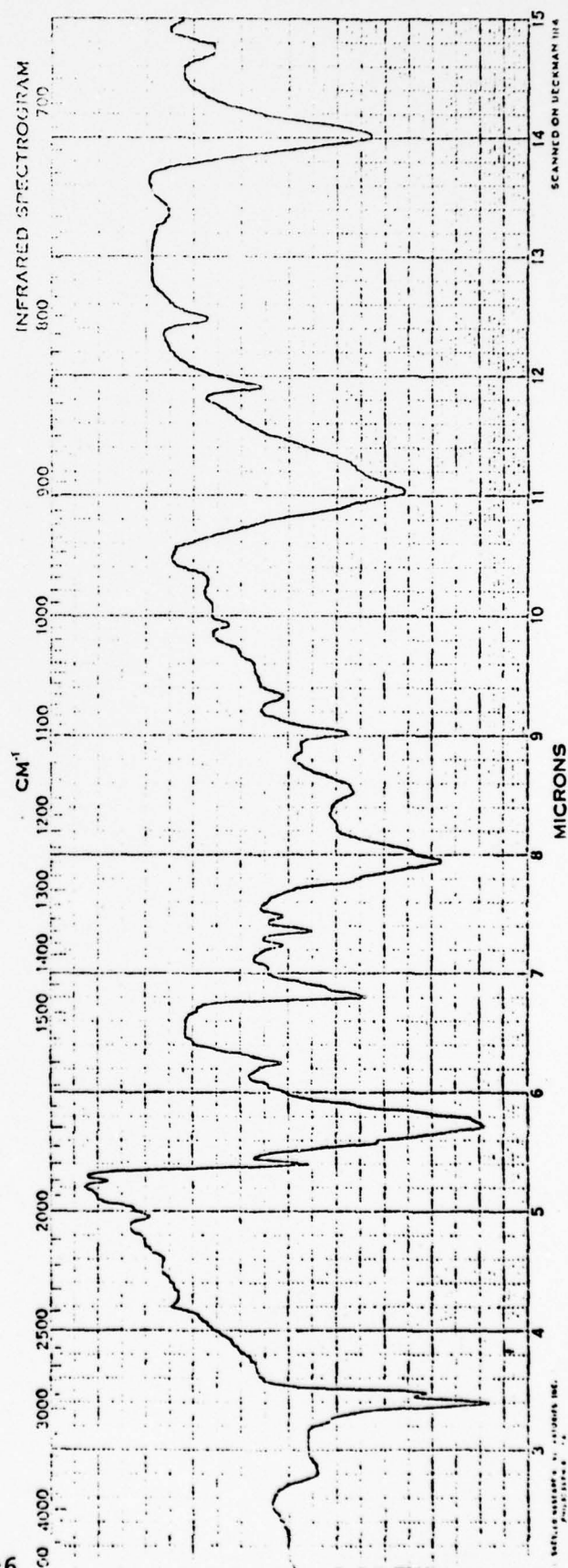
Visc. 20°C (60% in White Spirit) 12-18 poises

Oil 65% Phthalic Anhydride 25%

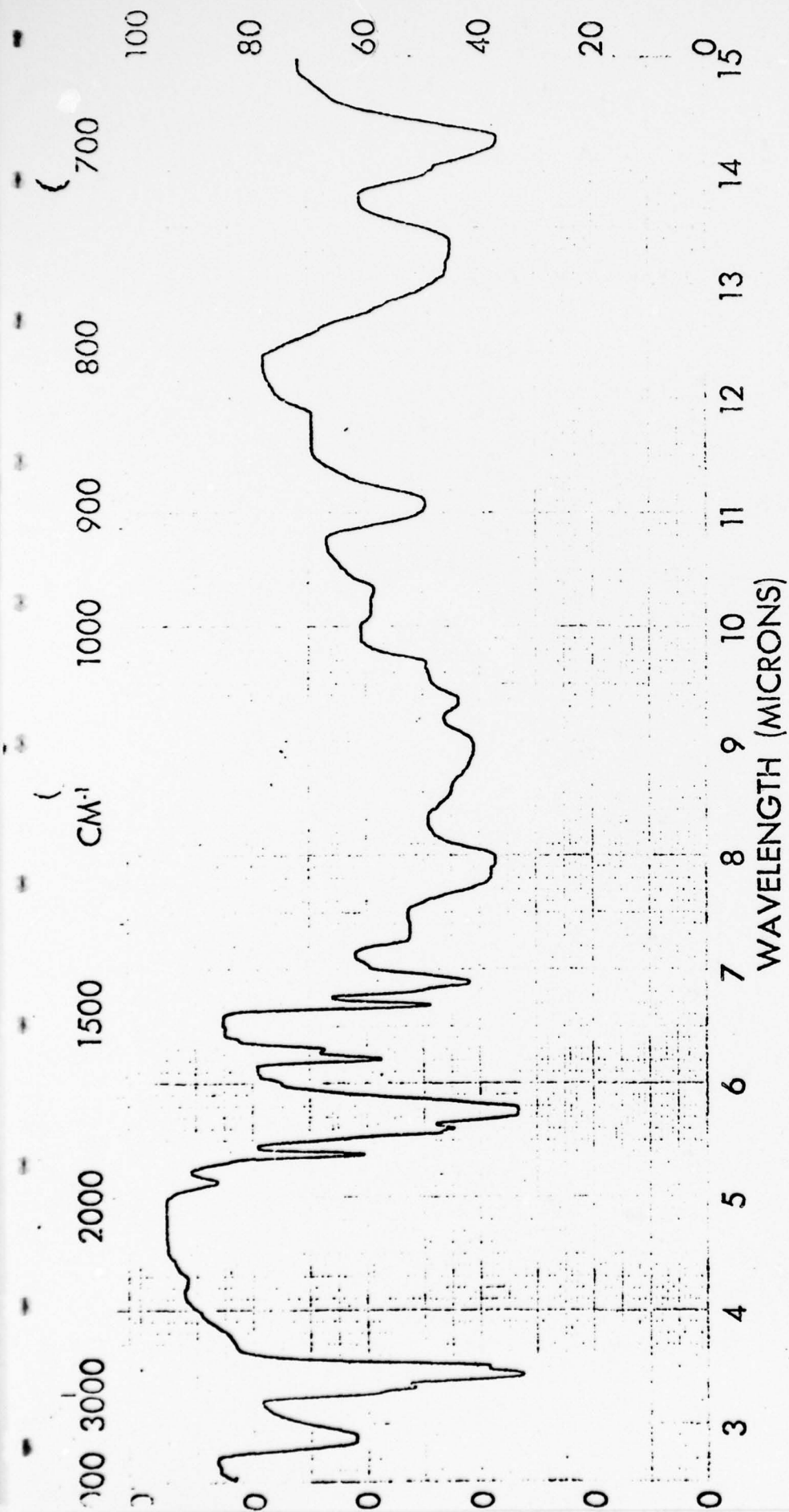
Source: Kunstsfabriek Synthese N.V., Holland  
Film

PYROLYZATES

8A-6



D 8745



SPECTRUM NO. <u>81323-R</u>		ORIGIN <u>Sadtler Research Laboratories, Inc.</u>		LEGEND _____		REMARKS _____	
SAMPLE <u>Cycopol S 102-5</u>		PURITY _____		1. _____		_____	
Styrene alkyd copolymer (Reference spectrum)		PHASE <u>Pyrolyzate</u>		2. _____		_____	
_____		THICKNESS _____		DATE _____		_____	
_____		_____		OPERATOR _____		_____	

SPECTRUM NO. \_\_\_\_\_  
SAMPLE \_\_\_\_\_

BA-12

Acrylic Rubber

Source: Borden Chemical Company

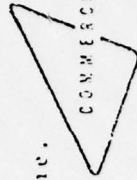
Between Salts

SADTLER

Research Laboratories, Inc.

© 1961

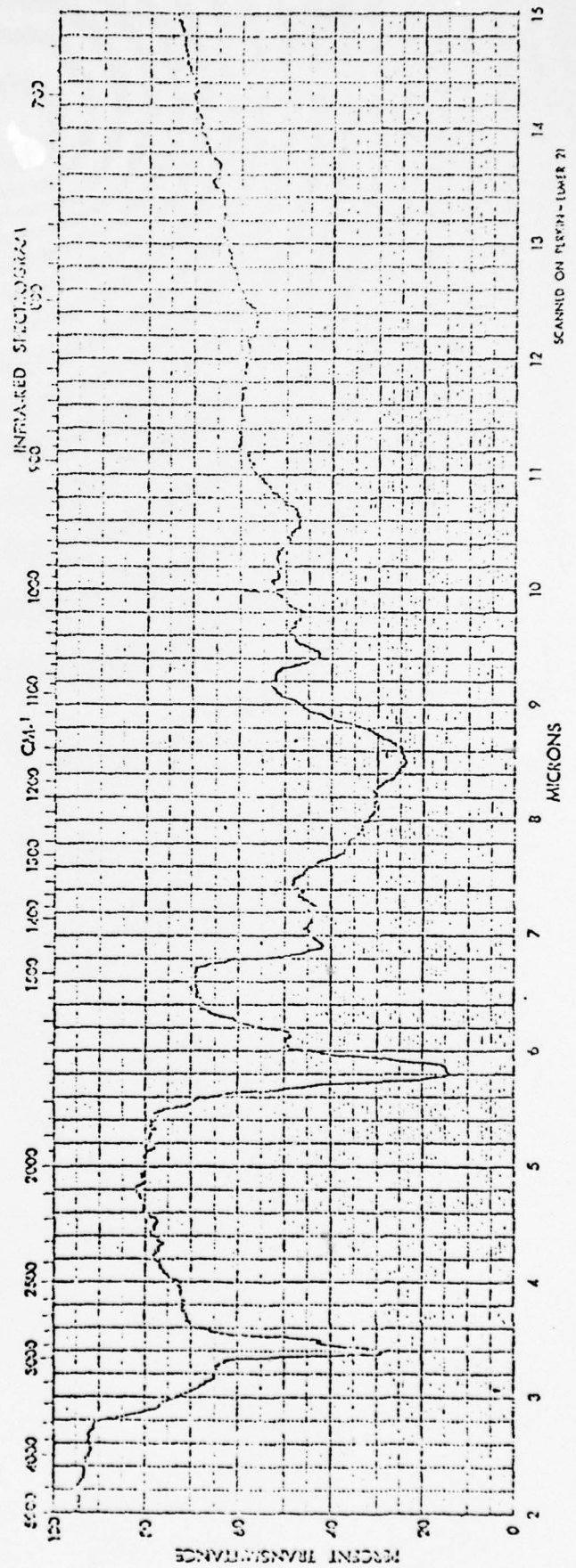
D 8420



COMMERCIAL-INFRARED

PYROLYZATES

8A-8



## CHAPTER 9

### RECOMMENDATIONS-NEW CONSTRUCTION

#### Purpose

The purpose of this Chapter is to present recommendations for new construction in order to preclude moisture problems in air conditioned buildings in humid climates. These recommendations are based upon the observations, discussions and analyses in the preceding chapters.

Specific recommendations are made for changes in existing design criteria and for additional criteria which will permit the avoidance of moisture related problems in air conditioned buildings in humid climates. See Chapter 8 for Paints, Coatings and Roofing.

#### Design Criteria Recommendations

The following changes in design criteria are recommended. The paragraph numbers shown refer to paragraphs in Chapter 5 for the various design publications. For convenience the notes from Chapter 5 are repeated prior to each recommendation.

##### A. Guide Specification Section 07232 - Ceiling, Wall and Crawl Space Insulation

1. Paragraph 6.1 calls for vapor barrier to be installed on the "interior (warm in winter) side of the construction".

A-1. The Guide Specification for ceiling, wall and crawl space insulation should be changed to suggest that vapor barriers (if used) should be installed on the exterior side of the construction in humid climates.

##### A. Guide Specification Section 07241 - Roof Insulation

2. Paragraph 6 calls for vapor barriers as follows:  
6.4 Poured Concrete Decks-Ventilating Felt

- 6.5 Precast Concrete Decks-Asphalt base sheet
- 6.6 Structural Cement-Fiber Decks-Asphalt base sheet
- 6.7 Wood Decks - Rosin-sized paper or unsaturated felt plus asphalt base sheet
- 6.8 Gypsum Decks - Ventilating Felt
- 6.9 Steel Decks - None shown

A-2. References to vapor barriers should be eliminated for roofs in humid climates.

- 3. Technical Note G calls for vapor barrier except for metal decks.

A-3. Do not require vapor barriers for roofs in humid climates.

A. Guide Specification Section 15 - Insulation of Mechanical Systems

- 4. Paragraph 5.2.1 does not require a vapor barrier jacket for unicellular insulation.

A-4. Vapor barriers should be specified for all types of pipe insulation including unicellular, for cold piping systems in humid climates.

D. NAFACINST 11012.114H - Design Guidance for Bachelor Enlisted Quarters

- 1. Paragraph II-I limits floor to floor height to 10'6" in air conditioned buildings.

D-1. Provide exemptions on floor to floor height requirements where necessary.

- 2. Most definitive drawings reference in Paragraph I-B provide floor to floor heights lower than 10'6".

D-2. Definitive drawings which preclude the use of duct systems in humid climates should not be utilized or required in those climates.

- 3. Paragraph V-A prohibits air to air heat pumps.

D-3. Permit the use of air to air heat pumps in humid climates including through the wall and window type heat pumps.

4. Paragraph V-B calls for inside "design" conditions between 75 and 78F and relative humidity of 50% or the outside design dewpoint, whichever is less.

D-4. In addition to specifying "design" conditions, requirements should be added to insure that humidity is controlled within the comfort zone during all hours of the year in humid climates.

5. Paragraph V-C1(d) calls for bathroom exhaust air to be replaced by infiltration and not included in load calculations.

D-5. Make up for bathroom exhaust air in humid climates should be continuously conditioned and not allowed to be infiltration.

6. Paragraph V-C generally requires that the cooling load calculations be done as tightly as possible.

D-6. Cooling load calculations should consider not only the design sensible and latent loads, but also the typical part load conditions for both sensible and latent.

7. Paragraph V-H1 calls for the largest possible temperature difference on chilled water systems.

D-7. In order to achieve dehumidification in humid climates the chilled water temperature difference should be as small as possible, consistent with economical piping and pumping costs.

8. Paragraph V-H2 suggests consideration of a separate ducted ventilation system in conjunction with fan coil units.

D-8. Separate ducted ventilation systems in conjunction with fan coil units should only be considered when the smallest fan coil units will still have a requirement to function under light sensible load conditions. Otherwise, reheat will probably be necessary.

E. DOD 4270.1-M - Construction Criteria Manual

1. Paragraphs 3-4.1C and 3-4.2B require bachelor officer and enlisted housing floor to floor heights to be the "practicable minimums" con-

sidering structural and mechanical systems.

E-1. No recommendation.

2. Paragraph 8-5.1B calls for inside "design conditions between 75 and 78F and relative humidity of 50% or the outside design dewpoint, whichever is less.

E-2. See D-4.

3. Paragraph 8-5.1E calls for insulation and ventilation of spaces above ceilings in conjunction with air conditioning of existing buildings.

E-3. Special care and attention must be utilized when air conditioning existing buildings in humid climates. Using ambient air for ventilation above ceilings, especially in multistory buildings, should not be recommended because of condensation and vapor flow problems.

4. Paragraph 8-5.1K calls for ceiling mounted application when using room fan coil units in areas with winter design temperatures of 15F or higher.

E-4. Fan coil units should not be utilized in humid climates with year round cooling.

5. Paragraph 8-5.3 calls for "A single central plant, or a single refrigeration unit" for buildings.

E-5. In humid climates with year round cooling multiple refrigeration units shall be used.

6. Paragraph 8-5.3B lists various types of buildings and limits of cooling load under which exceptions to the central plant or single unit requirement may be taken.

E-6. See E-5.

7. Paragraph 8-5.7A permits the use of a secondary or auxiliary refrigeration system when the "winter" air conditioning load is small.

E-7. The use of secondary or auxiliary refrigeration systems

should be required when there are many hours at light loads and/or where the air conditioning system operates under varying loads year round.

8. Paragraph 8-5.9 calls for a single chiller (in priorities 6,7 and 8) for loads between 130 and 800 tons, and one, two or three chillers for loads over 800 tons (based on an economic study). Where only personnel is involved the load shall not be "split".

E-8. See E-6.

9. Paragraph 8-5.10 suggests that air conditioning equipment be located outdoors to the greatest extent possible, except when in proximity to the ocean.

E-9. Add humid locations to the exception.

10. Paragraph 8-5.15B prohibits summer humidity control in priorities 6,7 and 8 except when the sensible heat factor is less than 0.65. Dehumidification control is permitted in tropical locations when the winter design temperature is higher than 65F.

E-10. Add to the exception in Priorities 6,7 and 8 . . . when the sensible heat factor is less than 0.65 "during any hours of operation throughout the year". Humidity control is required in air conditioned buildings in humid climates, unless it can be demonstrated that it is not necessary.

11. Paragraph 8-7.6 discusses condensation control for cold climates.

E-11. A paragraph should be added discussing condensation control for humid climates.

F. Design Manual-Mechanical Engineering - DM-3

Chapter 4 Section 4 Part 1

1. Paragraph 1a requires a minimum of 6 air changes per hour.

F-1. An exception should be provided for those applications in humid climates having low sensible heat factors.

2. Paragraph 2 requires a maximum of 0.125 CFM/SF or exhaust + 10% or 10 CFM per person in quarters (with smoking).

F-2. See D-5. In windy locations in humid climates the percentage excess of ventilation air over exhaust air should be 20 to 30%, or the design wind velocity, whichever is higher.

#### Chapter 4 Section 4 Part 2

3. Paragraph 1 has no requirement for exhaust air for toilet areas in BEQ's and BOQ's.

F-3. Establish toilet exhaust requirements for BEQ's and BOQ's.

4. Paragraph 2 requires toilet areas to be maintained under a negative pressure.

F-4. Toilet areas in air conditioned buildings in humid climates should be maintained under a negative pressure with respect to adjacent rooms (by means of exhaust fans) and under a positive pressure with respect to ambient conditions. Exhaust fans need not operate all the time. Natural ventilation of toilet areas in air conditioned buildings in humid climates should be prohibited.

#### Chapter 5 Section 2 Part 3

5. Paragraph 2 covers the determination of the time of maximum load.

F-5. A determination should be made of the minimum cooling load in order to establish the ability of the air conditioning system to provide comfort conditions at minimum cooling load.

#### Chapter 5 Section 2 Part 5

6. Table 5-5 calls for long period occupancy spaces to be maintained at 40 to 50% RH.

F-6. Expand the relative humidity range to 40 to 60% relative humidity.

#### Chapter 5 Section 2 Part 7

7. Paragraph 2 calls for a minimum of one

air change per hour for the purpose of calculating loads.

F-7. In humid climates less than one air change per hour may be used as the minimum if it can be shown that the type of construction and local wind velocity will yield less than one air change per hour of infiltration.

Chapter 5 Section 2 Part 9

8. Paragraph 6 requires calculation of moisture permeance for very low room dewpoints.

F-8. Whenever the ambient design dewpoint temperature exceeds the room design dewpoint temperature by more than 20F, moisture permeance shall be calculated.

Chapter 5 Section 2 Part 13

9. Paragraph 2a requires computation of the supply air quantity based on room sensible heat gain.

F-9. Where latent heat gain is substantial, air quantity shall be based on latent heat gain.

10. Paragraph 2b(1) requires a minimum of six air changes per hour (with bypass if necessary).

F-10. See F-1.

11. Paragraph 2b(3) calls for reheat for spaces with low sensible heat factors in order to maintain 6 air changes per hour.

F-11. In buildings in humid climates with highly variable sensible cooling loads and/or long hours of operation at light sensible cooling loads, reheat is required in order to maintain comfort conditions. Consideration shall be given to utilizing condenser heat and/or recovered heat for the purpose of reheat.

Chapter 5 Section 3 Part 2

12. Paragraph 1a restricts return air from living quarters.

F-12. Remove the restriction on return air from living quarters.

Chapter 5 Section 4 Part 2

13. Paragraph 2c discusses the requirements for control of fan coil units.

F-13. In applications in humid climates with long hours at light sensible load conditions, fan coil units cannot be controlled to achieve comfort conditions.

14. Paragraph 2d calls for condensate drain piping for fan coil units with certain exceptions.

F-14. Fan coil units shall not be utilized in air conditioned buildings in humid climates operating on cooling year round.

Chapter 5 Section 5 Part 5

15. This part discusses the various means for controlling refrigeration equipment under part load operation.

F-15. In humid climates with long hours of operation at light loads multiple chillers should be utilized so that the smallest chiller is not required to short cycle or utilize hot gas bypass.

Chapter 5 Section 5 Part 9

16. Paragraph 1b(2) suggests 85F condenser water temperature.

F-16. Rather than specifying a specific cooling tower water temperature, it should be established at something like 7F above the ambient design wet bulb temperature or based on a life cycle cost study. Consideration should be given to the use of draw through cooling type towers in lieu of blow through type in humid climates with year round cooling based on a life cycle cost analysis.

17. Paragraph 3f calls for capacity control on cooling towers to maintain 75F water temperature.

F-17. Remove the restriction on 75F cooling tower water temperature and suggest that the condenser water temperature be as low as possible consistent with the recommendations of the refrigeration equipment manufacturer and dependent upon a life cycle cost evaluation of the fan energy versus the compressor energy. Consideration should also be given to the life cycle costs of draw through type cooling towers versus blow through type cooling towers.

Chapter 5 Section 7 Part 1

18. This part discusses the performance characteristics of air cooling equipment at full load conditions.

F-18. A life cycle cost analysis shall be made in order to establish the optimum cooling coil face velocity. An analysis should be made of the dehumidification capability of the air handling system at light loads in humid climates.

Chapter 5 Section 7 Part 6

19. Paragraph 2 discusses condensate removal.

F-19. In humid climates with continuous cooling operation, consideration should be given to a supplementary drain that would handle any overflow of the drain pans.

Chapter 5 Section 16 Part 1

20. Paragraph 1b calls for insulation with vapor barriers.

F-20. When continuous operation with cold fluids exists throughout the year, provisions shall be made for access for replacement of insulation. Such lines shall not be run in or above occupied spaces to the maximum extent possible.

Chapter 5 Section 16 Part 2

21. Paragraph 2c(1) does not require drain piping to be insulated.

F-21. Where condensation can occur on drain piping it shall be insulated.

22. Paragraph 3c does not specifically call for cooling condensate drain pans and piping to be insulated.

F-22. Insulation should be provided for cooling drain pans and piping as indicated in F-21.

#### Chapter 5 Section 17 Part 4

23. Paragraph 1c limits face and bypass control unless outside air is dehumidified.

F-23. The use of face and bypass control should be discouraged in humid climates, except in conjunction with a specific humidity control system. This type of control should be used only when it can be demonstrated that humidity will be controlled under all conditions of load.

24. Paragraph 2c suggests a coil leaving air thermostat when constant cooling and dehumidification are required.

F-24. Where humidity control is essential, the use of a humidistat in addition to a thermostat for the purpose of controlling humidity by means of cooling coil discharge temperature is suggested.

#### Chapter 5 Section 18

25. Paragraph 4 calls for overtemperature alarms only for electronic equipment facilities.

F-25. In air conditioned buildings in humid climates alarms should be considered for high chilled water supply temperature and high relative humidity in typical zones.

#### Chapter 5 Section 19 Part 1

26. Paragraph 2d calls for water drips to be piped to a floor drain.

F-26. In mechanical equipment rooms in humid climates the design of equipment pads and floor slopes should consider condensation

dripping from air conditioning equipment.

Chapter 5 Section 19 Part 4

27. Paragraph 1 lists a number of items for architectural coordination.

F-27. Add a paragraph outlining the coordination necessary between the architect and mechanical engineer in conjunction with the design of air conditioned buildings in humid climates.

G. A-E Guide - Pacific Division

1. Paragraph 6.8.2e requires a statement of the control system needed to meet inside temperature and humidity requirements.

G-1. Add the requirement for a statement of the ability of the control system to meet indoor humidity requirements at light sensible load conditions.

Appendix H-Attachment A

2. Paragraph 8 calls for the use of economy cycle.

G-2. Eliminate the requirement for economy cycle in humid climates.

Appendix H-Attachment B

3. Paragraph 3 calls for foil backed insulation or gypsum board.

G-3. Eliminate the requirement for foil in humid climates.

Appendix H-Attachment C

4. This attachment sets forth guidance for preparing computer energy analyses.

G-4. The energy analysis computer program shall consider the dehumidification performance of the air conditioning system and should consider the vapor flow through the structure when it appears to be of any significance.

H. A-E Guide - Southern Division

1. Appendix X Paragraph D(4)(C) calls for a Statement of any special dehumidification requirements.

H-1. A statement should be made regarding any dehumidification requirements in a building and the manner in which they will be handled to insure comfort control under all conditions of operation.

J. Technical Guidelines For Energy Conservation In New Buildings

1. Paragraph 3.2.2.4(2) suggests the use of a runaround system within an air handling unit in order to achieve some reheat without the use of new energy.

J-1. In humid climates where there would be substantial need for reheat in order to obtain humidity control, such a system should be carefully considered.

2. Paragraph 3.2.4 suggests various types of refrigeration heat recovery which may be used for heating or reheat.

J-2. Same as J-1.

3. Paragraph 3.3.20 calls for a minimum 20F rise in chilled water systems.

J-3. See D-7.

L. Design Manual - Troop Housing - DM-36

Chapter 1 Section 6

1. Paragraph 2c calls for fan and coil units for air conditioning, while paragraph 2a(4) calls for room type fan coil units for individual rooms. (Enlisted)

L-1. Eliminate the requirement to utilize fan coil units in air conditioned troop housing in humid climates.

Chapter 3 Section 3

2. Paragraph 1c calls for fan coil units and no air conditioning for toilets, corridors, stairways or storage rooms. (Officer)

L-2. See L-1. Remove the prohibition on the air conditioning of toilet areas, although it is not necessary to supply air directly to toilet rooms. Remove the prohibition on the air conditioning of stairways unless they are exterior and have free air circulation. Remove the prohibition on the air conditioning of corridors unless they are insulated, vapor sealed and ventilated. Remove the prohibition on the air conditioning of storage rooms unless the materials to be stored therein will not be subject to damage from mold or mildew.

M. Design Manual - Architecture - DM-1

Chapter 1 Section 4

1. Paragraph 2 suggests that climate be carefully considered before starting design.

M-1. Special consideration should be given to air conditioned buildings in humid climates in view of the potential moisture problems.

Chapter 2 Section 2

2. Paragraph 4d discusses climate related design criteria for tropical humid zones.

M-2. Consideration should be given to subdividing tropical humid climates into island and inland humid climates. Consideration should also be given to subdividing design considerations in humid climates into those for non-air conditioned buildings and those for air conditioned buildings.

3. Table 2-1 (Roofs) requires that insulation not be used over concrete slabs, that the underside of the slab be coated with an organic vapor barrier, flat roofs be avoided, cellular glass insulation is satisfactory, vegetable fiber board is unsatisfactory, insulation should be applied beneath roof slab, and that vapor barriers be used under insulation when it is above the roof slab.

M-3. See M-2.

4. Table 2-2 (Walls) requires that coatings be used to reduce moisture penetration and deter algae growth, shadow grooves not be used and that jalousies not be used for air conditioned spaces.

M-4. See M-2. An experimental study should be undertaken to simultaneously correlate the moisture vapor resistance and algae growth deterring capabilities of the various finishes used on buildings in various types of humid climates.

5. Table 2-3 (Wall Materials and Finishes) requires that where moisture is not a problem, gypsum and cement plasters are satisfactory, portland cement plaster and cement plaster on lath not be used in humid areas, organic fiber wallboards not be used when subject to wetting and drying, exposed masonry is satisfactory when not subject to moisture, ferrous metal door bucks not be used, organic fibrous insulations are subject to moisture damage and should not be used and that cellular glass should be used rather than fibrous glass, mineral wool and organic fiber insulation materials.

M-5. See M-2.

Chapter 2 Section 4 Part 5

6. Paragraph 6b discusses the effects of condensation.

M-6. See M-2.

Chapter 3 Section 2 Part 3

7. Paragraph 2b covers the application and selection of insulating materials.

M-7. See M-2. This paragraph should be expanded to include consideration of vapor barriers on the exterior of air conditioned buildings in humid climates and the specific requirements for vapor barrier permeance where high vapor pressure differentials exist.

8. Table 3-4 shows the moisture resistance of insulating materials.

M-8. See M-2.

Chapter 3 Section 2 Part 5

9. Table 3-6 lists the moisture resistance properties of partition facings.

M-9. See M-2.

General Recommendations

Climate

In humid climates the 1% design wet bulb temperature should be utilized for calculation of latent loads and for sizing of cooling towers.

The determination of the application of humid climate design criteria should be based upon the values shown in Table 6-1.

Thermal Performance

Insulate walls and roofs to maintain surface temperature above ambient dewpoint temperatures.

Insulate projections from the building, columns and foundations in order to maintain surface temperatures above the ambient dewpoint temperatures.

Minimize corners and areas which permit air stagnation.

Moisture Performance

Materials utilized on the exterior of buildings should have high vapor resistance, while materials utilized on the inside of buildings should have lower vapor resistance.

Infiltration through the building should be minimized by careful detailing, sealing and caulking.

Infiltration through windows should be minimized by specifying according to industry standards and by careful installation. Control over the occupants may be necessary to insure that windows and doors remain closed.

#### Building Configuration

Corridors and hallways should be air conditioned unless the partitions between them and conditioned spaces are treated as exterior walls and they are adequately ventilated.

Exterior shading devices should be limited to shading fenestration only.

Ventilation above suspended ceilings should not be permitted. Spaces above suspended ceilings should be considered as conditioned space and provisions made to allow for circulation of conditioned room air above the ceiling.

Toilet rooms and closets should be considered as conditioned spaces and should be provided with louvered doors.

#### Air Conditioning Systems

When using central air conditioning systems use all air type systems with constant dehumidification.

Allow the use of unitary air conditioning systems, especially in existing buildings.

Keep air handling units out of the conditioned space.

Make provisions for supplementary drainage for air handling unit cooling coil drain pan overflows.

Make provisions for replacement of pipe insulation.

Provide for continuous conditioning of outside air and only introduce it through air conditioning units.

Keep the building pressurized.

Insure the control of humidity in the space by the selection of the air conditioning system type and the means for controlling it.

Don't supply saturated air at variable temperatures.

Special care and attention should be paid to the quality of field workmanship especially in central air conditioning systems.

Provide alarms for chilled water temperature and space relative humidity.

Use multiple chillers.

#### Fan Coil Units

Fan coil units shall not be used in humid climates.

#### Exhaust Systems

Natural ventilation shall not be used in air conditioned buildings for toilet rooms.

Exhaust registers should be placed in proximity to the generation of moisture. In the case of toilet rooms they should be placed at the shower location.

## CHAPTER 10

### RECOMMENDATIONS - EXISTING BUILDINGS

#### Purpose

This Chapter discusses recommendations for improving and for correcting the moisture problems associated with existing buildings in humid climates. While the recommendations for new construction apply to existing buildings as well, it is recognized that it is not feasible to apply all of these recommendations to existing buildings.

Numerous projects have been undertaken in existing buildings with moisture problems in an attempt to improve or correct these problems. Most of these projects have been accomplished either by local forces or under minor construction contracts. In every case the basic structure and air conditioning system of the building has not been significantly altered. In most every case the conditions have been improved but the problems have not been corrected. See Chapter 8 for Paints, Coatings and Roofing.

#### Improvements

The most significant improvement in the performance of air conditioned buildings with fan coil units can be accomplished by operating the air conditioning system in accordance with the design. Generally, this implies maintaining the design chilled water temperature, having the fan coil unit controls function properly and insuring that the drain pans and drain lines are kept from clogging.

Further improvements can be made by changing the performance of the existing air conditioning systems so that they are capable of providing increased dehumidification under light sensible load conditions. This can be accomplished by increasing chilled water flows, reducing chilled water temperatures, reducing air flows, and making changes in controls.

Unfortunately even the most ideal combination of the above techniques will not be able to correct the problems, they will only be able to improve conditions, since controlled dehumidification will still not be achieved and comfort conditions provided.

Even if changes were made to the structure of the building in accordance with the recommendations for new construction in conjunction with changes to the fan coil units, the problems still cannot be considered as corrected, since these actions provide no tolerance for the conditions that are encountered in the operation of the buildings.

#### NBS Tests

Tests were conducted by the National Bureau of Standards on a 300 CFM fan coil unit to determine performance characteristics and to establish recommendations for improving humidity control. The results of these tests are included in a draft "Report on the Evaluation of a Fan-Coil Unit Operation Under High Latent, Low Sensible Load Conditions" by James Y. Kao, dated October 31, 1977.

The tests used a room sensible load of 1,750 Btuh which may be low compared with the fan coil unit capacity, but does not represent loads as low as those that would be actually experienced

during operation, especially at night. Even under those conditions the lowest dew point achieved was 63.5F which would yield 68 percent relative humidity at 75F room temperature. With lighter sensible loads the dew point temperature would tend to rise, thus yielding even higher relative humidity in the space.

The NBS report makes three recommendations:

1. Modify fan coil unit controls from cycling chilled water valves and continuously running fans to cycling fans and continuously circulated water coil.
2. Reduce fan coil air flow rates.
3. Replace the unit mounted thermostats with wall mounted thermostats.

While Recommendation #1 will help to improve conditions compared to what they have been, it will still not solve the problem of being able to control the space relative humidity. So long as the space sensible loads are not high, the amount of dehumidification will not be adequate to maintain space relative humidity within an acceptable range continuously.

While Recommendation #2 will also help to improve conditions, it will not suffice to maintain space relative humidity within acceptable conditions. Even though the unit will run longer, at light sensible loads it will still run an insufficient length of time to achieve adequate dehumidification.

While Recommendation #3 will more truly sense space temperature, it will not measurably change the space humidity.

The degree to which these recommendations will improve conditions in existing buildings will depend primarily on how oversized the

existing fan coil units are. The more oversized the unit is, the more improvement there will be. However, regardless of fan coil unit size, implementing these recommendations fully will still not provide continuous control over space humidity and will therefore not provide a satisfactory solution to the problems.

#### Corrective Actions

The only way that these moisture problems will be corrected in existing buildings will be to adapt the recommendations for new buildings to the maximum extent technically feasible. This will require modifications to the building itself and replacement of the entire air conditioning system in the building with one that is capable of controlling humidity within the comfort zone, thus providing the necessary tolerance to the conditions encountered in the operation of the buildings.

Since the structure and configuration of each existing building is sufficiently different, the specific actions to be undertaken for correction will also differ. The buildings should be addressed on a one by one basis.

For the air conditioning systems the corrective actions can proceed in either of two directions. Either the central chilled water systems may be retained or unitary packaged air conditioning units may be employed.

If the central plant chilled water concept is to be retained it will be necessary to replace the airside systems with ones that are capable of providing full time continuous dehumidification control. This implies the use of some form of reheat which may usually be obtained by the use of condenser water or a run around

system. The airside system concept would by necessity be the all air type, either reheat, variable air volume or constant volume.

This would then require the installation of air handling units which could be located on the roof or in fan rooms. This may necessitate using either storage rooms or taking over an occupied room. Depending upon the structural and architectural configuration of each building the air handling units may be located on a per floor basis or on a per wing basis serving multiple floors.

With the central plant concept great care should be taken to insure reliability of operation of the chilled water system, especially with regard to maintaining design chilled water temperatures. Consideration must also be given to the operating practices for the chilled water supply system and the availability of qualified personnel to insure that those conditions are maintained.

In some existing buildings structural and architectural limitations may preclude using central chilled water and air handling units. These limitations would include the availability of space and the ability to run duct work either horizontally (by virtue of limitations on head room) or vertically (by virtue of limitations on penetrating structural slabs). In these cases unitary packaged systems such as through the wall units may prove to be the most economical solution. This solution would usually necessitate the installation of an electrical distribution system in the building to serve the units since the capacity of the

existing electrical distribution system would typically be inadequate.

The most significant changes to the buildings themselves would involve the selection and application of paints and finishes with respect to permeability and the evaluation of exhaust systems. In the non-residential type buildings the control systems for air conditioning would require the most attention to insure humidity control.

CHAPTER 11  
CONFIRMATION

Purpose

The purpose of this Chapter is to discuss the major recommendations contained in this report in light of another field investigation during the most severe weather conditions in August 1978. Several operating air conditioning systems were instrumented and the results reported and the performance of a number of other buildings were observed.

Instrumentation

The following instruments were utilized:

1. Psychrometer
2. Bacharach Recording Hygro-Thermograph
3. Bacharach Temperature and Humidity Recorder
4. Bacharach Temperature Recorders
5. Various Thermometers

Generally the Hygro-Thermograph was utilized for measuring room temperature and humidity conditions, while the temperature and humidity recorder was used for measuring outdoor conditions. The temperature recorders were utilized for measuring supply air temperatures and chilled water temperatures.

Test Results - Naval Station - Guam

Pages 11A-1 and 11A-2 show the recordings for Room 8 in BEQ 8 at the Naval Station in Guam for August 7, 1978.

BEQ8 is a masonry construction Bachelor Enlisted Quarters which has been recently air conditioned utilizing air handling units. The building consists of two floors with

a single loaded corridor. The corridor is enclosed.

Instrumentation was set up in a first floor end room which had a thermostat controlling the temperature for all rooms on that floor from the central air handling unit serving that floor. The air handling unit is supplied by chilled water from a central plant that serves a number of BEQ's.

During the period of the test the outdoor temperatures ranged from 78 to 90F, while the outdoor relative humidity ranged from 72 to 90 percent. The room humidity ranged from 62 to 66%, while the room temperature remained virtually constant at 77 to 79F. During this time the supply air temperature to the room was 68 to 69F.

There were two North facing windows in the room and while the drapes were left open there was not sufficient solar heat gain to cause any noticeable change in the room load and therefore there was almost no change in the supply air temperature to the room, even though this room had the thermostat controlling the entire floor. During the period of the test the weather was clear. The chilled water supply temperature to the air handling unit was in the 54-58 range.

So long as a room thermostat controls the cooling coil discharge temperature and so long as the loads are less than the full capacity of the equipment, the supply air temperature will never be required to be low enough to do adequate dehumidification.

This case also reflects the problems inherent in oversizing any type of air conditioning system that does not have spec-

ific humidity control. So long as the dehumidification is dependent upon the room sensible heat gain, the dehumidification will not take place to any sufficient degree unless the sensible cooling load is somewhere near the capacity of the installed air conditioning system.

Test Results - Naval Communication Station - Guam

Pages 11A-3 and 11A-4 show the temperature and humidity recordings in BEQ 296, Room 202 of the Naval Communications Area Master Station in Guam. This building is three stories of masonry construction with unenclosed corridors. Air conditioning is provided by a central chilled water plant located on the roof supplying fan coil units in the rooms. Chilled water piping runs above a suspended ceiling and has caused numerous problems due to condensation and dripping. The insulation has obviously become saturated over time and therefore permits condensation to occur on the exterior of the vapor barrier jacket because there is no substantial thermal resistance remaining.

The fan coil units were located in soffits in each room. Mold growth was present on the ceiling. The fan coil fan was set on "High" and the thermostat was turned down to its minimum setting.

During the period of the test the outdoor temperatures ranged from 76 to 82F, while the outdoor relative humidity ranged from 88 to 98 percent. The fan coil discharge temperature ranged from 60 to 62F with the higher temperatures being late in the afternoon and early evening and the lower

temperatures occurring early in the morning through mid-day. The room temperature ranged from 69 to 72F with the higher temperatures being in the afternoon and the lower temperatures being in the middle of the night. The room relative humidity remained almost constant at 79 percent RH.

With the ambient air almost completely saturated and generally at a somewhat higher temperature than the room there was only a very small sensible cooling load during the period of the test. The fan coil unit was therefore not called upon to do very much cooling and therefore did almost no dehumidification.

#### Test Results - Naval Air Station - Cubi Point

Pages 11A-5 and 11A-6 show the temperature and humidity recordings for Room 114 at the BOQ at Cubi Point Naval Air Station in the Philippines. This building is constructed of masonry and has enclosed corridors. The building is air conditioned with a central plant supplying chilled water to fan coil units in each room.

During the period of the test the ambient air temperatures were almost constant at 75F while the relative humidity was almost constant at 100%. The room temperature remained relatively constant at 69 to 70F with lower temperature during the night. The room relative humidity ranged from 50 to 57%. The fan coil unit supply air temperature remained relatively constant at 48F and the chilled water supply temperature remained relatively constant at 44F.

This building has been the subject of extensive attention

and the humidity conditions appear to be about the lowest of any of the fan coil units that were observed. However it was noted that the room temperature was being maintained at a low level thus causing an increased sensible cooling load which in turn resulted in sufficient dehumidification to bring the humidity under control. This room had a refrigerator which helped to add some sensible cooling load.

#### Test Results - Summary

The psychrometric chart on page 11A-7 shows the room temperature conditions measured and the ASHRAE comfort envelope. It can be seen that none of the rooms instrumented operated within the comfort envelope at any time.

While the BOQ at Cubi Point was able to achieve relative humidities in the 50 to 60% range it did so at the expense of overcooling the space. The BEQ at the Naval Station in Guam was close to the comfort envelope yet suffered from humidity high enough to cause mold growth because the sensible cooling load was light and the capacity of the air conditioning system was more than adequate and the air conditioning system did not permit control over humidity. The BEQ at the Naval Communications Station in Guam utilized a typical fan coil system and as a result was substantially away from the comfort envelope.

Thus it can be seen that it is essential to operate the air conditioning system properly and to have an air conditioning system that will provide specific control over humidity in order to achieve comfort conditions.

#### Other Observations

Architectural devices used for purposes such as shading or overhangs or walkways should be thermally discontinuous from the conditioned space. This will avoid the cold radiator effect and will virtually eliminate the tendency to have the architectural projections below the ambient dew-point temperature and thus avoid condensation and mold growth. Doing this means that the use of cantilevered structures should be discouraged to the maximum extent feasible.

A number of other buildings were investigated where exterior mold growth was prevalent. One such building was the Chief Petty Officers Club at the Naval Station in Guam which had egg crate type projections on the windows. These projections were about 18 to 24 inches out from the building and the egg crates were about 2 by 3 feet.

Mold growth was prevalent on most areas of the egg crates, but especially noticeable on the wall immediately above the projection and on the lower surfaces of the egg crate projections. This was most probably due to the fact that these areas received the most rain and at the same time were also cold due to the cold radiator effect. The inside upper surfaces of the projections were almost totally free of mold since they received almost no rain. The inner portions of the projection showed very little mold growth even though they were cold surfaces probably because there was very little moisture that could penetrate that far into the egg crate.

Another building with noticeable mold growth was Building 3190 at the Naval Station in Guam which apparently is used for offices. This building is of masonry construction with eyebrows over the windows projecting approximately 2 feet from the building. Here mold growth is quite evident on the eyebrow itself and on the wall immediately above the eyebrow and on the wall running down either side of the windows to the ground. The obvious reason for mold growth in these areas were the presence of rain water in conjunction with a cold surface.

Also observed were several BEQ modernization projects in which air conditioning was being added at the same time that the buildings were being renovated. Insulation was being installed with metal studs and drywall. The installation of the insulation was sloppy and not continuous as well as the insulation being compressed to fit around piping and wiring. In addition to providing uneven thermal quality in some areas there was inadequate insulation. The installation of metal studs provides a thermal bridge from a conditioned to an unconditioned space and should be considered very carefully before being utilized.

In addition, the insulation that was used had a vapor barrier. In some cases we observed vapor barriers on the inside and in other cases on the outside. Vapor barriers as a part of the insulation probably should not be utilized. Rather, one should depend upon the vapor resistance of the exterior finishes since it is very impractical to expect that the vapor barriers on the insulation will provide

adequate vapor resistance because it is difficult if not impossible to properly seal the joints and holes.

With much of the chilled water distribution piping being suspended from covered walkways there were problems evident with condensation on the exterior of the vapor barrier jacket of the insulation. This is obviously due to the insulation becoming saturated over a number of years and loosing its thermal performance thus resulting in exterior surface temperatures that permit condensation to exist. Beside the annoyance of having this condensation drip off the piping it also provides a climate in which mold growth occurs readily.

There were some instances where aluminum louvers were used as part of the exterior wall where fan coil units were located. It was obvious that no insulation was utilized between the fan coil units and the louvers since condensation occurred on the surface of the louvers due to being cold from being adjacent to the fan coil units.

Some buildings also utilize sliding exterior metal louvers to serve as a shading device. These sliding louvers are mounted in channels above and below the windows and are operated by the occupant. Since the channels must be away from the window there is a space of two or three inches where water can accumulate on the outside of the building and not flow away and not be exposed to sunlight, thus creating a condition in which mold growth exists.

Several cases were noted where there was condensation on

the frame of exterior metal doors as well as on the edges of those doors. This usually existed where the doors were shaded from the sunlight and therefore the moisture could not evaporate.

Where buildings use exterior walkways which are structurally a part of the building, provision should be made to make sure that they drain adequately away from the building. Otherwise when accumulations of moisture are present and the building is air conditioned mold will be formed.

#### Fan Coil Units

Fan coil systems should not be used in humid climates, especially in buildings with low sensible heat gains. Utilizing fan coil units alone would generally result in having to operate at room temperatures lower than those generally accepted for comfort conditions in order to do sufficient dehumidification to achieve comfort and prevent mold growth.

With fan coil units alone comfort conditions could typically be achieved only when the capacity of the units were proper to begin with (not oversized) and when the sensible cooling load was at or near its design capacity. This would occur with high ambient temperatures plus solar heat gain plus maximum occupancy. While these conditions can and do exist, the frequency with which they exist simultaneously is very limited. As a result during most hours of the year the actual sensible cooling load is substantially below the maximum design sensible cooling load so that dehumidification will not be achieved unless

the room thermostat is set at temperatures lower than 70F which are unacceptable from a comfort standpoint.

Consideration was also given to the use of fan coil units in conjunction with a central dehumidified air supply system. While such a system could be designed and operated to achieve comfort conditions it would be essential to employ reheat in each room or zone. The reason for this is that the dehumidified air would typically be supplied at 50 to 55F and would therefore have some sensible cooling capability. Such a system would require extremely careful attention to maintain design chilled water temperatures. For the many hours when very light sensible loads exist even the small quantity of dehumidified ventilation air would overcool the space and would therefore require some form of reheat for temperature control.

In most of the types of buildings in which such a system would be utilized the difference between the design sensible cooling load and the sensible cooling load that would be handled by the central dehumidified air system is small so that the capacity required for a fan coil unit is very small. In the case of living quarters the fan coil unit capacity would be only a fraction of the smallest unit that is commercially available thus making for a relatively expensive installation.

So long as a central dehumidified air supply system is being considered and so long as individual room or zone reheat is going to be utilized, such a system could be increased in size, provided with return air capability, and

utilized to handle the entire cooling load.

One possible alternative that was considered and rejected was the use of fan coil units with a central dehumidified air supply that had reheat in the air handling unit. The basic reason why this system was rejected was because of the substantial energy penalty that would result. In such a system it would be first necessary to cool and dehumidify the ventilation air and then reheat it to say 75F. Even though the reheat would probably be obtained from condenser heat rejection there would still be no net sensible cooling benefit from the central air supply system. Rather, the central air supply system would be supplying "neutral" dehumidified air to each of the spaces. The fan coil units located in the rooms would then be in the position of having to do all of the sensible cooling that would be necessary in each room, rather than depending upon the sensible cooling capability of the central air supply system. The obvious result is "double cooling". The only advantage to this concept is that it eliminates the need to provide individual room by room reheat.

Another alternative that was considered and rejected was the use of individual room dehumidifiers in conjunction with fan coil units. Such a concept would be similar in function to the one previously described except that an additional sensible heat gain would result from the operation of the dehumidifier thus causing even more cooling energy to be consumed by the fan coil units. In addition there would be a substantial maintenance problem and the need to provide an electrical distribution system through-

out each building to each room in order to provide sufficient power for the operation of the dehumidifiers.

In all likelihood the relatively poor operating efficiency of multiple small dehumidifiers for the purpose of dehumidifying would result in even higher energy consumption than the use of central chilled water for the purpose of dehumidifying in any kind of central air handling system.

Another problem that would exist with such a concept is that the dehumidifiers would cause a continuous accumulation of water in the rooms along with wet coils which would be conducive to mold growth. Even if the dehumidifiers were connected to permanent drains the wet coils would still exist. Connections to a permanent drain would further increase the installation cost.

#### Operating Conditions

Very few changes were noted in the operating conditions of chilled water systems. Most chilled water plants continue to be operated at chilled water temperatures much higher than design. Instruments and gauges are not kept in calibration making it even more difficult for an operator to determine if the systems are operating properly.

Especially in those cases where a central chilled water plant serves a number of buildings with long runs of chilled water piping it is even more essential to carefully control the operation of the plant. With long runs of chilled water piping and insulation on the piping that becomes saturated over time it was observed that there were chilled water temperature rises of as much as 10 and 15

degrees from the chilled water plant to the furthest building being served. In those cases even if the chilled water plant were operated properly the chilled water temperatures at the more remote buildings would be inadequate to provide the necessary dehumidification.

Even though some of the chillers are marked to show 42 or 44F chilled water supply temperatures the thermostat in the control panel is set at higher temperatures. In addition, many of the larger chillers have electric demand limiting switches which were frequently found to be set as low as 40 and 50%, thus not permitting the chilled water plant to operate at sufficient capacity to provide the necessary chilled water temperature.

In discussions with some of the operating personnel it was determined that they had never received specific instructions as to the operating conditions to be maintained. They seem to have very little sense of the critical importance of maintaining the proper chilled water supply temperature and the relationship that it has to the proper operation of the air conditioning systems in the buildings that the plant serves.

### Summary

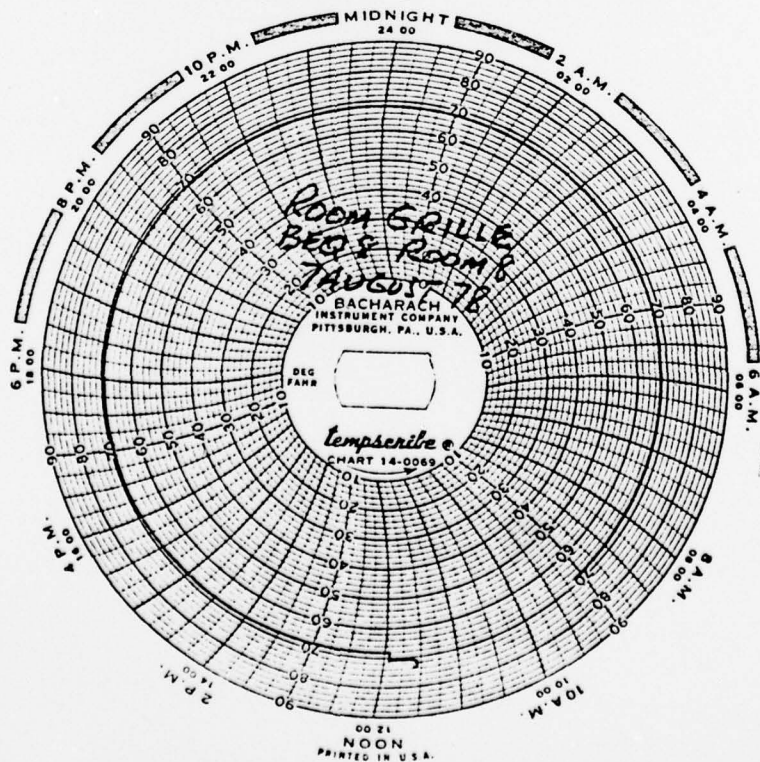
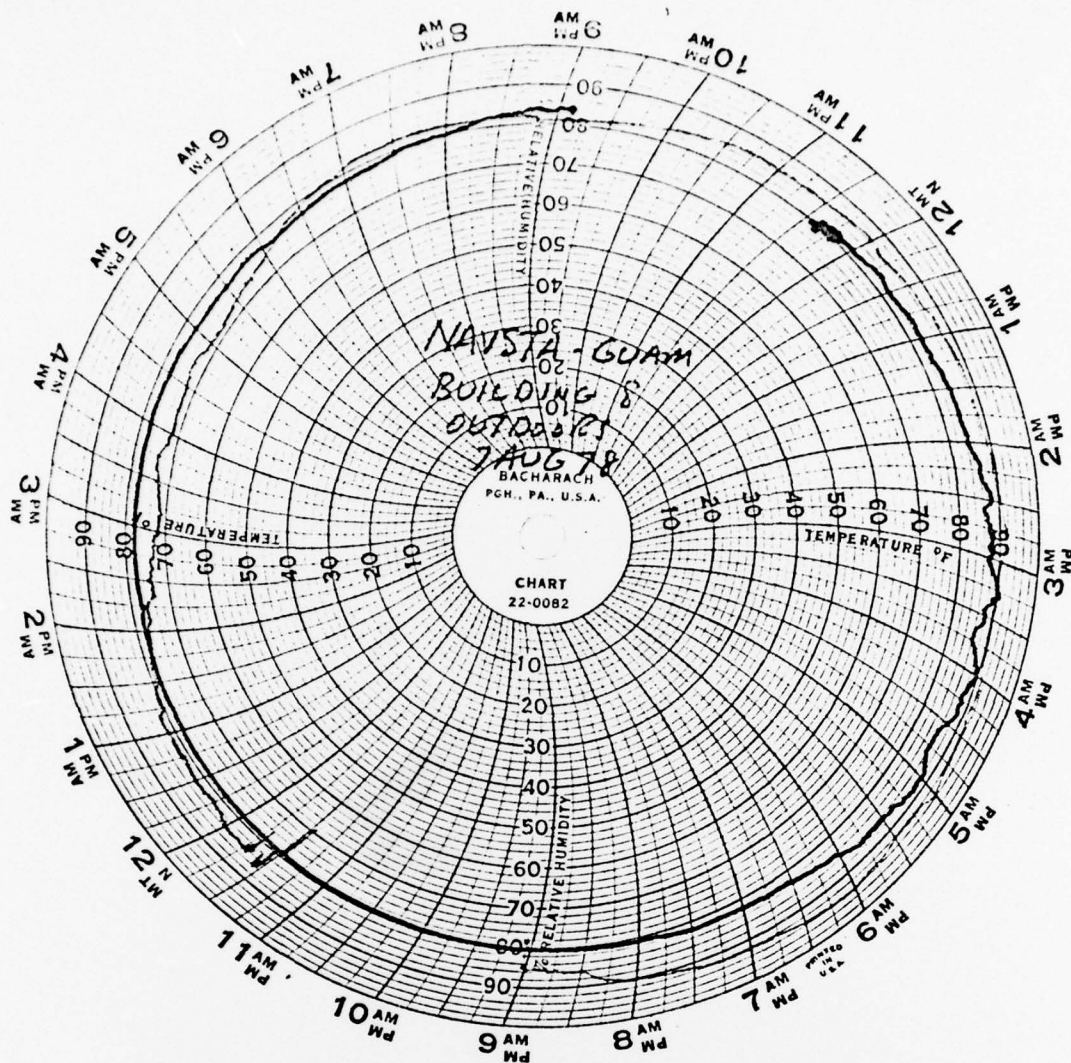
Even with the projects that have been accomplished to attempt to fix the fan coil unit systems and the increased attention to the operation of the chilled water plants we still did not find one building with fan coil units that was operating satisfactorily.

In those recently constructed or air conditioned buildings where variable volume systems were employed, the conditions were more satisfactory than with fan coil units since the variable volume system is capable of tolerating a wider range of chilled water temperatures while providing some dehumidification.

In order to achieve satisfactory comfort conditions and preclude the growth of mold it is essential to have an air conditioning system that provides continuous and specific control over humidity. The only way of achieving specific control over humidity in humid climates is to use reheat. We did not observe any buildings in which this was being done.

Continue the use, under careful observation, of textured exterior coatings.

Continue the use and upgrade the installation of adhered elastomeric roof systems.

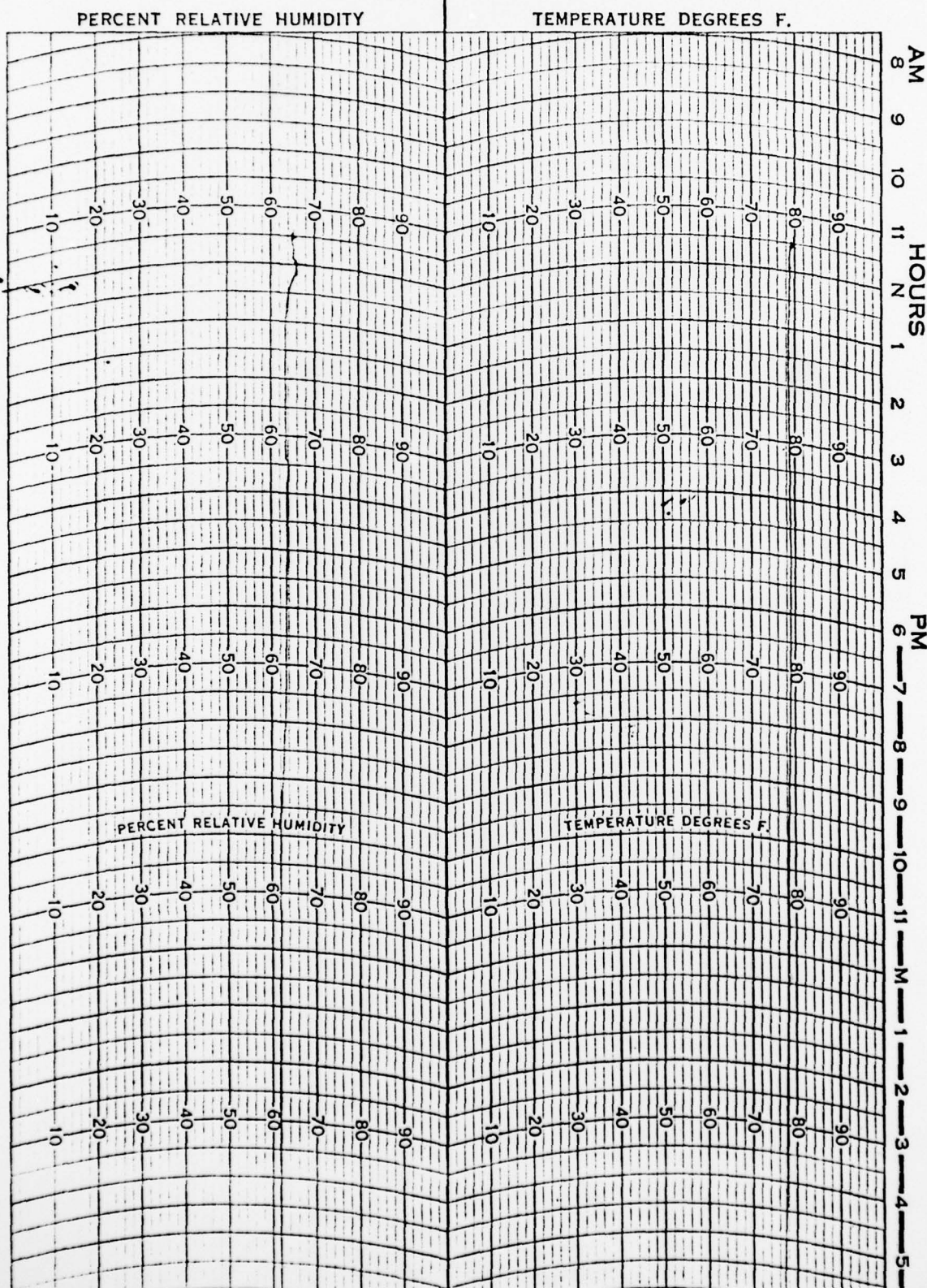


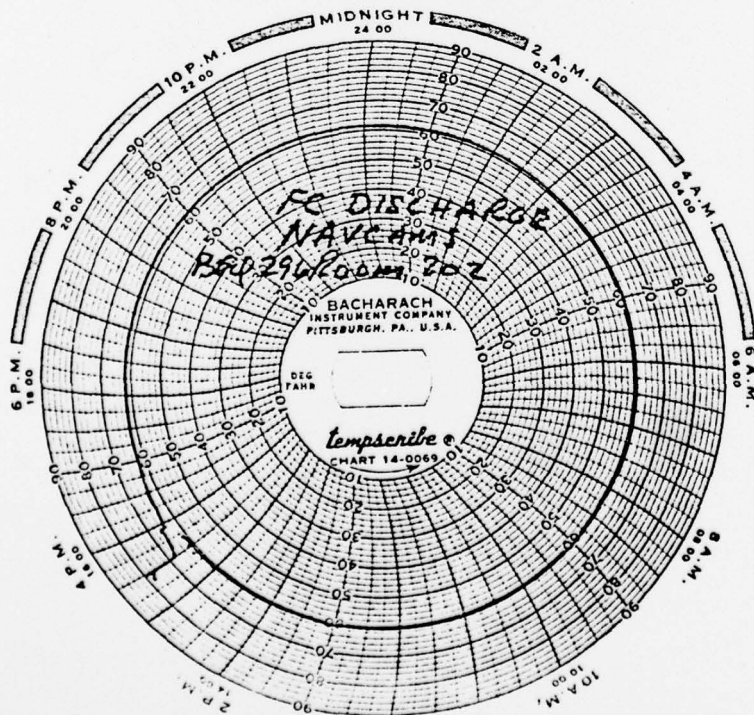
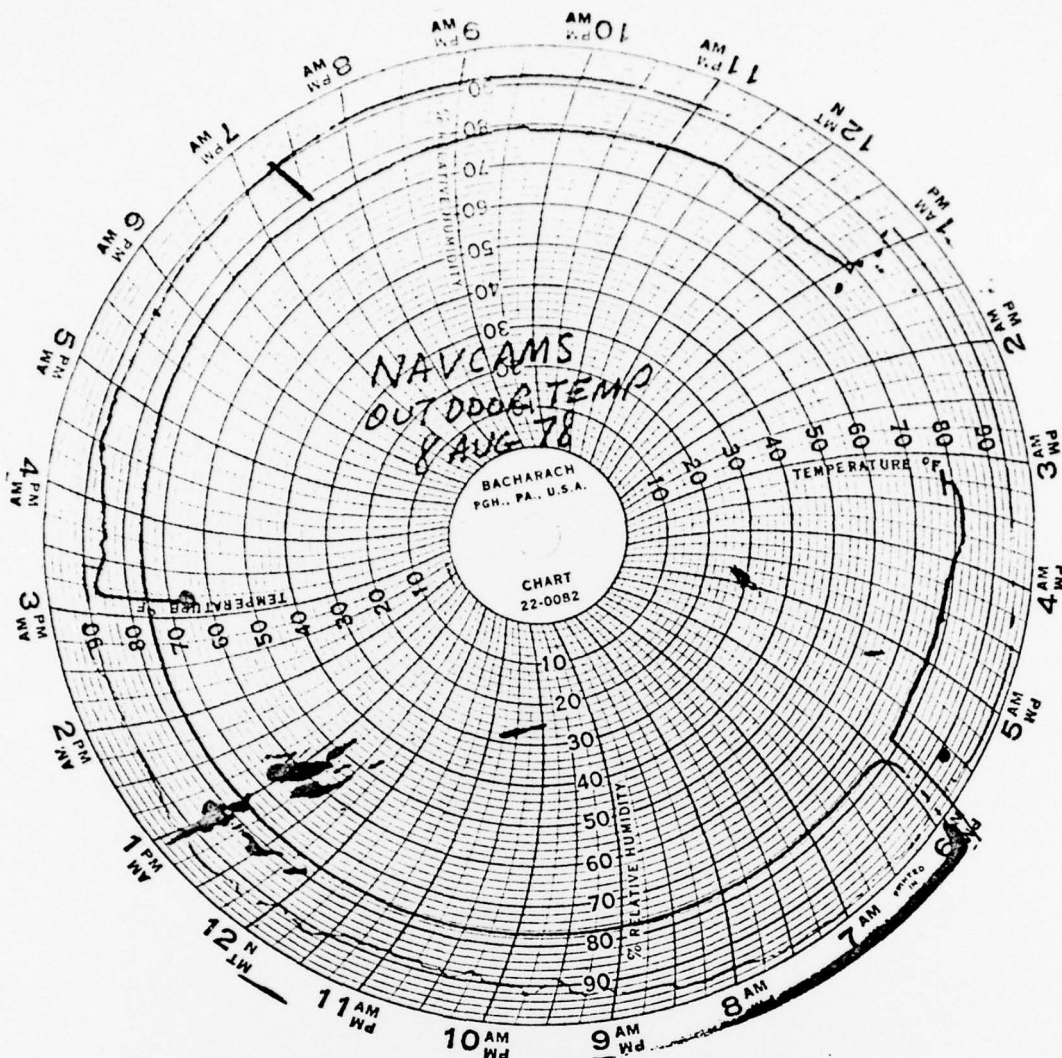
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CHART NO. 22-0085

STATION NAVSTA GUAM BEQ 8 ROOM 8  
RECORD DATE 7 AUGUST 1978  
REMARKS FIRST FLOOR END ROOM - NEXT TO T'STAT





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HYGRO-THERMOGRAPH

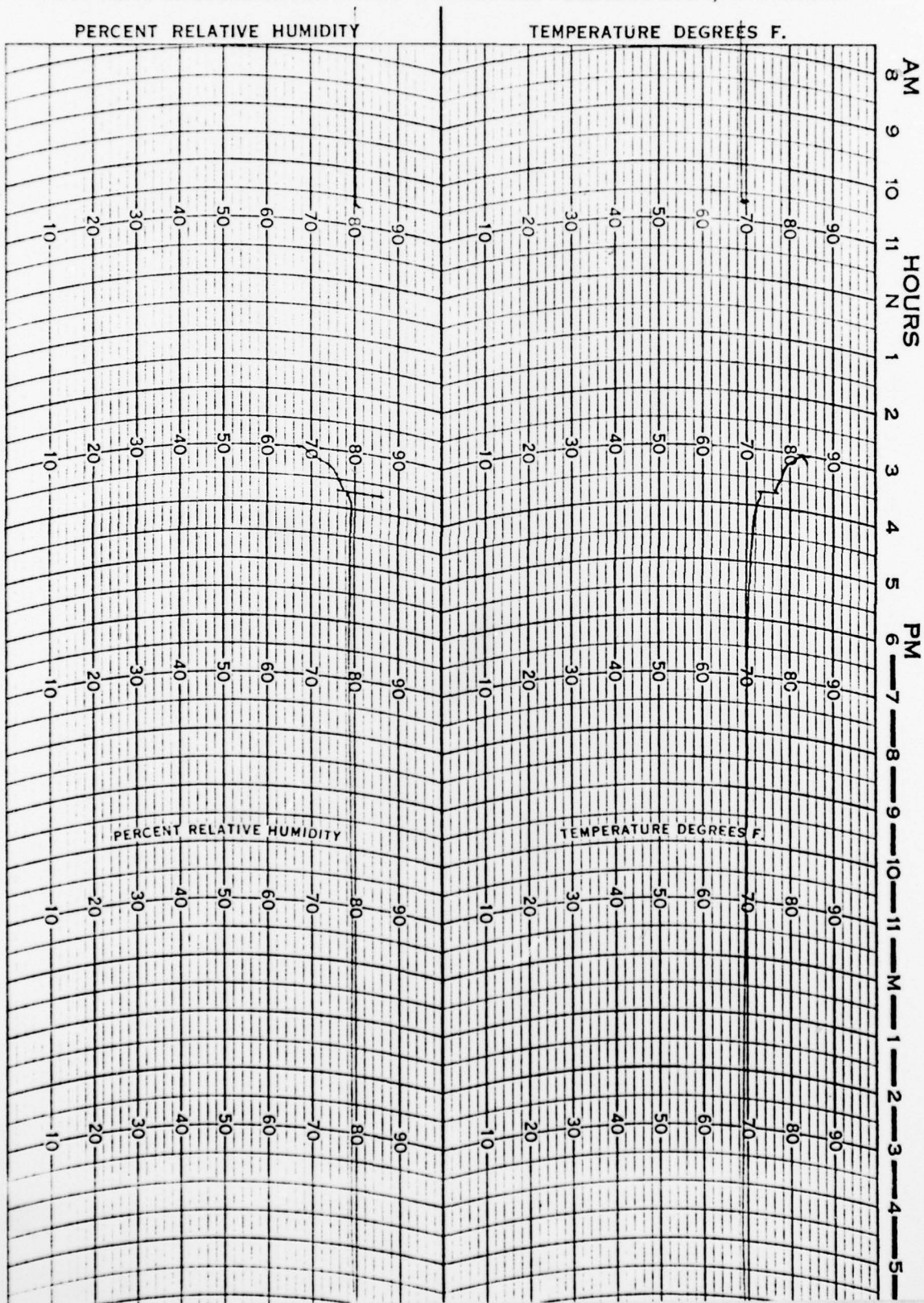
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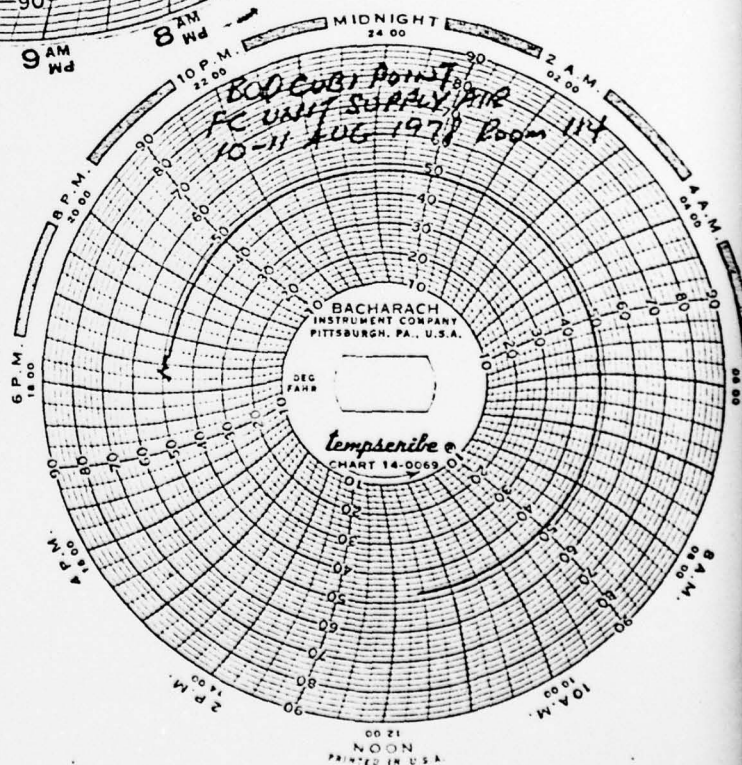
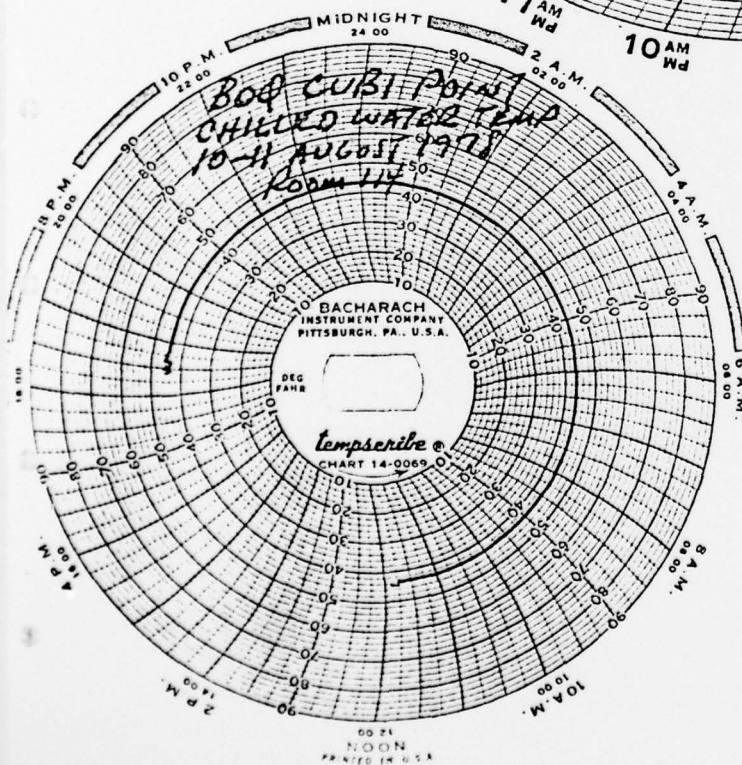
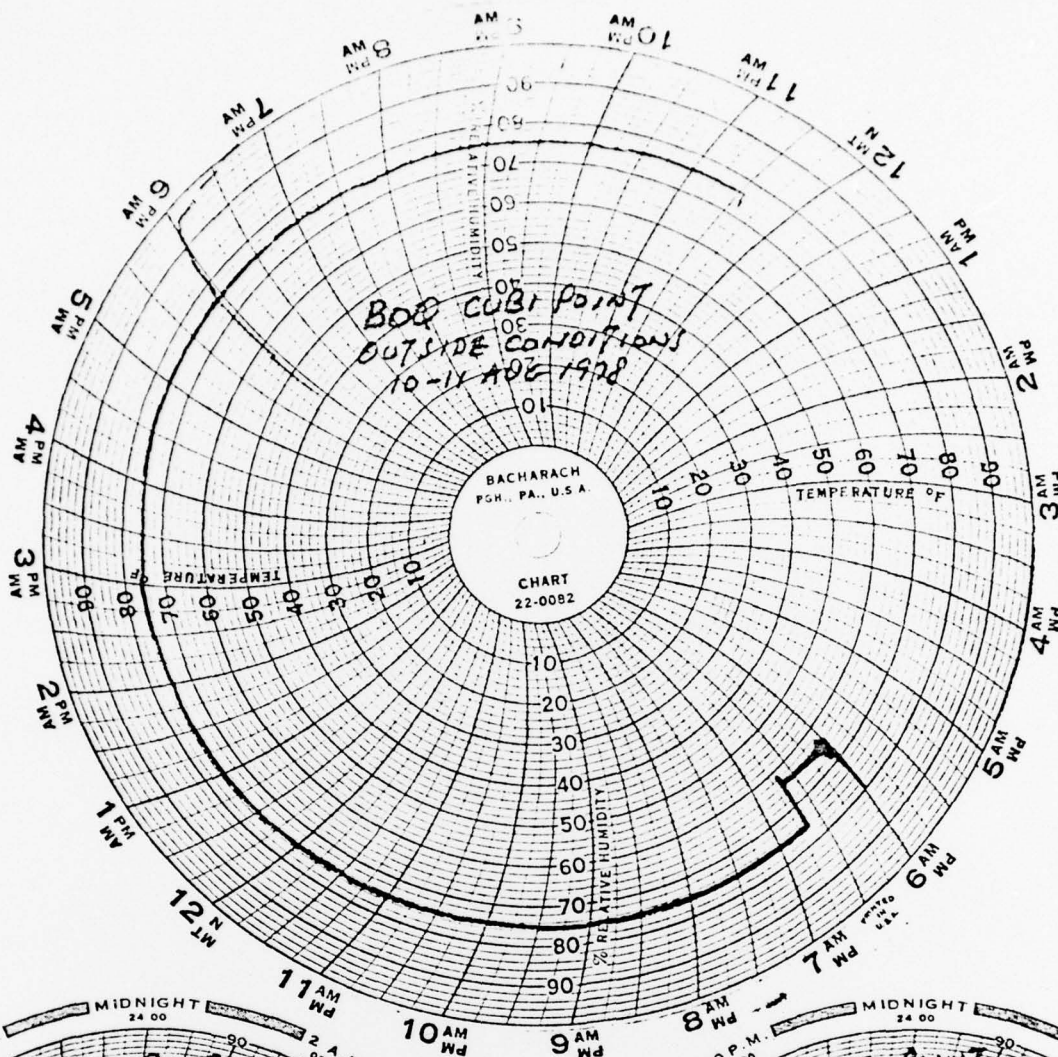
PITTSBURGH, PA., U.S.A.

CHART NO. 22-0085

STATION NAVCAMS GUAM BEQ 296 ROOM 202  
RECORD DATE 8 AUGUST 1978  
REMARKS 2ND FLOOR MIDDLE ROOM - FAN COIL UNIT



11A-4

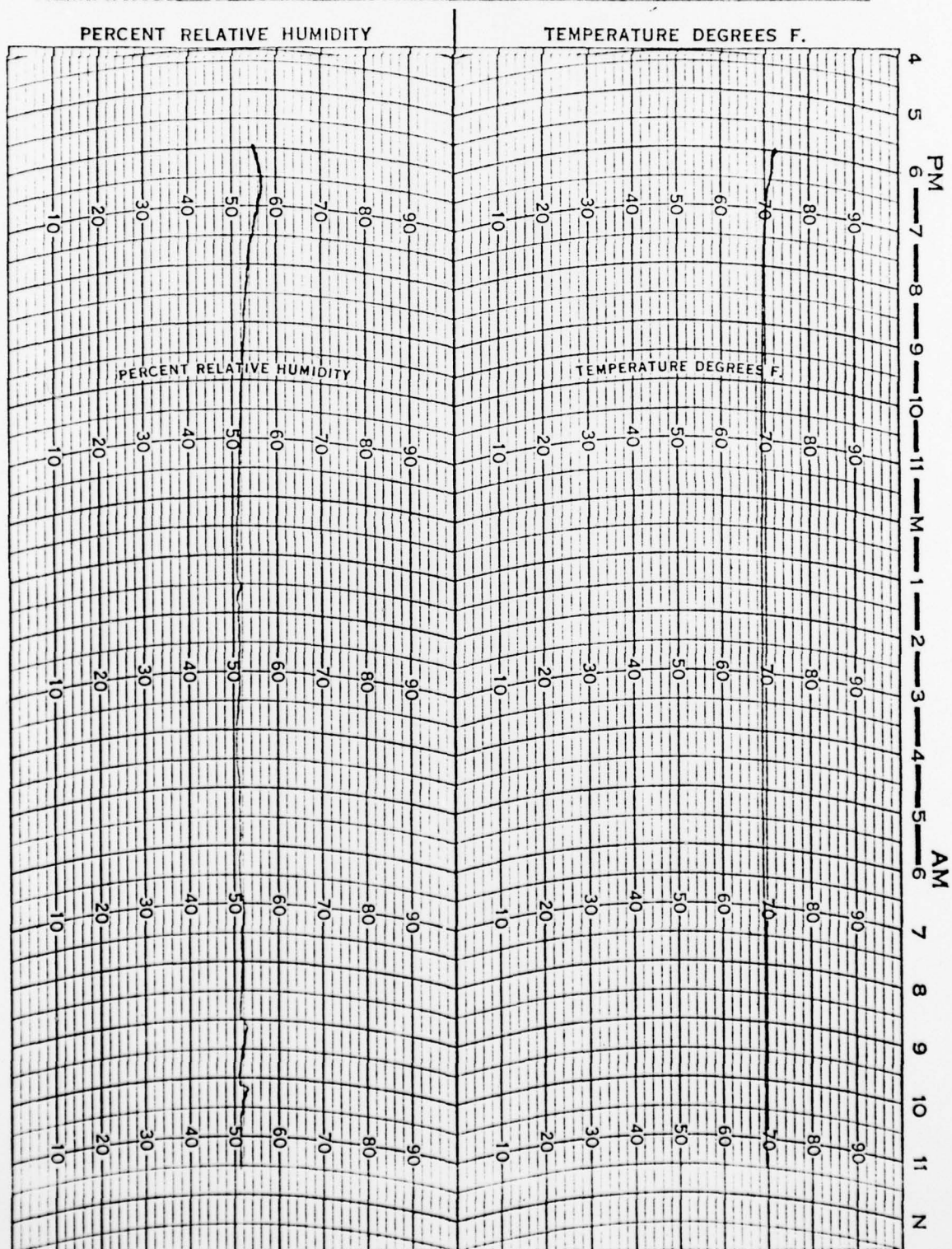


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STATION BOQ CUBI POINT ROOM 114 INDOOR CONDITIONS  
RECORD DATE 10 AUGUST 19 78  
REMARKS BUILDING 8254

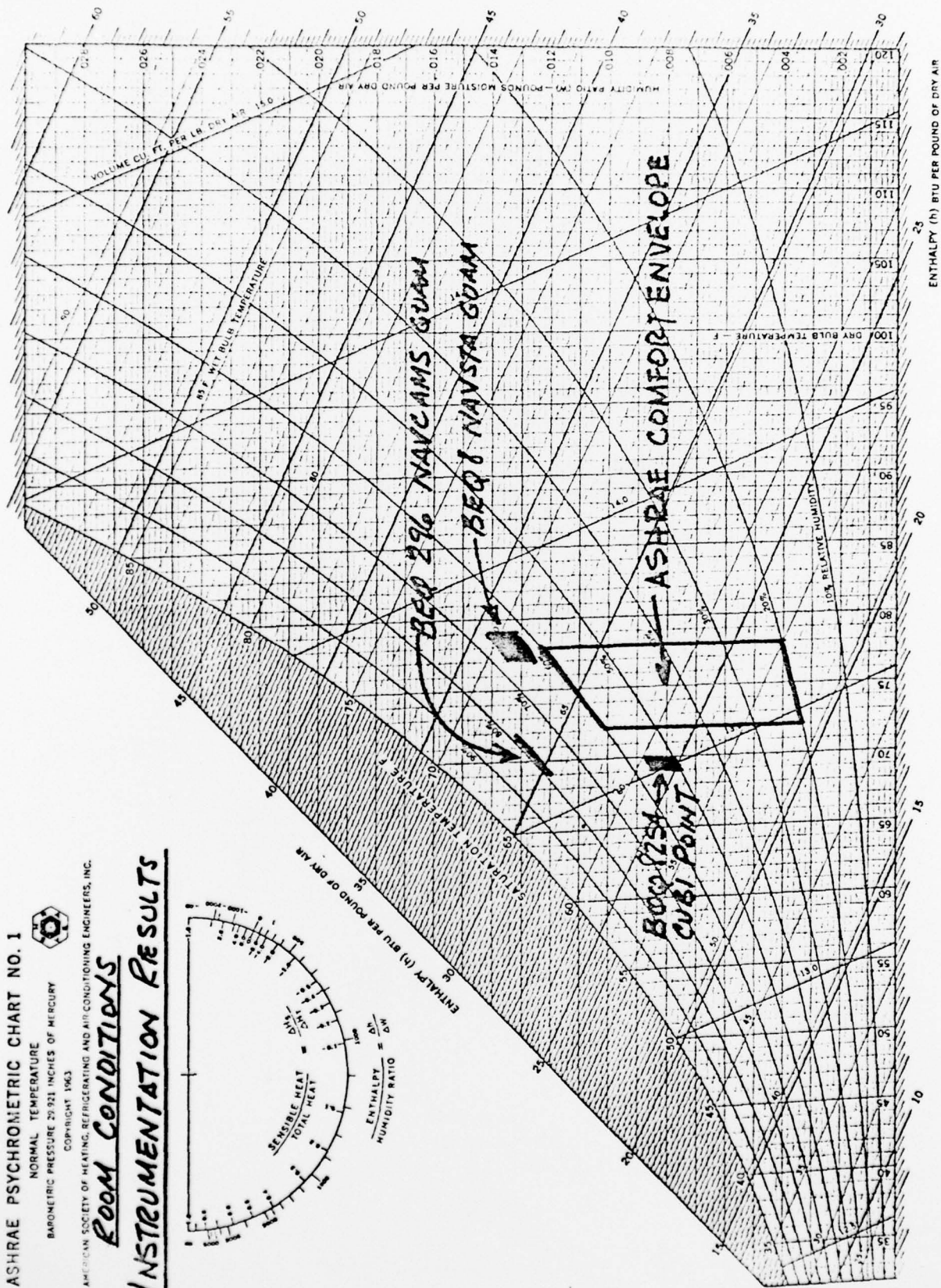
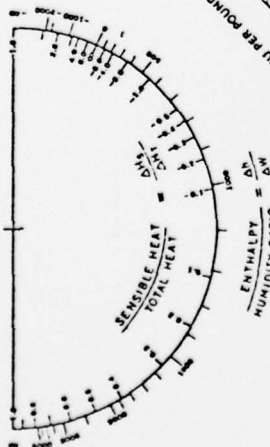


11A-6

# ASHRAE PSYCHROMETRIC CHART NO. 1

NORMAL TEMPERATURE  
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY  
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AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.

## Room Conditions Instrumentation Results



## CHAPTER 12

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